The Role of the NSF Broader Impacts Criterion in Enhancing Research Ethics Pedagogy

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Abstract: The National Science Foundation's Second Merit Criterion, or Broader Impacts Criterion (BIC), was introduced in 1997 as the result of an earlier Congressional movement to enhance the accountability and responsibility as well as the effectiveness of federally funded projects. We demonstrate that a robust understanding and appreciation of the NSF BIC argues for a broader conception of research ethics in the sciences than is currently offered in Responsible Conduct of Research (RCR) training. This essay advocates augmenting RCR education with training regarding broader impacts. We demonstrate that enhancing research ethics training in this way provides a more comprehensive understanding of the ethics relevant to scientific research and prepares scientists to think not only in terms of responsibly conducted science, but also the role of science in responding to identified social needs and in adhering to principles of social justice. As Universities respond to the mandate from America COMPETES to "provide training and oversight in the responsible and ethical conduct of research" we urge institutions to embrace a more adequate conception of research ethics, what we call the Ethical Dimensions of Scientific Research (EDSR), that addresses the full range of ethical issues relevant to scientific inquiry, including ethical issues related to the broader impacts of scientific research and practice.

Keywords: ethical dimensions of scientific research, responsible conduct of research, extrinsic ethics, intrinsic ethics, social justice, broader impacts criterion

1. The NSF Broader Impacts Criterion

The NSF's Second Merit Criterion was introduced in 1997 as the result of an earlier Congressional movement to enhance the accountability and responsibility as well as the effectiveness of federally funded projects. The 1993 Government Performance Results Act (GPRA) required federal agencies to measure the effectiveness of their programs. Part of the NSF's response was to streamline their review criteria from the original four criteria to two. The first criterion focuses on the intellectual merit of the proposed project and research capability and capacity of the investigators; the second criterion requires consideration of the broader social impacts of the research.

The mission of the NSF has always included attention to the broader impacts of science; however by streamlining the criterion into intellectual merits and broader impacts, and adopting the policy of not reviewing proposals that do not explicitly address both criterion, the 1997 changes have had the effect of focusing attention on this criterion. As was set out in the National Science Foundation Act of 1950 (Public Law 810507), the NSF aims "To promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes."

The NSF identified the following as desirable outcomes from its investments:

- Discoveries at and across the frontier of science and engineering;
- Connections between discoveries and their use in service to society;
- A diverse, globally-oriented workforce of scientists and engineers;
- Improved achievement in mathematics and science skills needed by all Americans; and
- Timely and relevant information on the national and international science and engineering enterprise. [1]

As is clear from this list, the NSF's mission is to balance excellence in scientific and engineering research with the broader impacts of that research upon i) the educational and research infrastructure, ii) the diversity of the fields themselves, as well as iii) supporting projects with positive social impact.[1]

The introduction of the Broader Impacts Criterion (BIC) [2] has required that principle investigators and proposal reviewers learn to justify and evaluate proposals based not only on the intellectual merit of the proposed project and research capability and capacity of the investigators, but also on the consideration of how the research will extend its relevance beyond the community of researchers and into the wider social milieu. As both a means (as a part of reflexive and anticipatory thinking on the part of the PIs and reviewers) and as an ends (having intended positive impacts as one of the goals for research outcomes) the Broader Impacts Criterion (BIC) has been successful, at the very least, in pushing publicly funded researchers to address how their scientific endeavors contribute to the broader goals and values of the communities in which they operate.

2. America COMPETES and the Broader Impacts Criterion

The BIC and the ethical issues it raises have been so far, unfortunately, mostly absent from current pedagogy in Research Ethics. In this essay, we will argue that this is a two-fold mistake. Research Ethics training that is limited to Responsible Conduct of Research (RCR) overlooks the importance of science not only being *responsible,* but also *responsive.* As we will demonstrate in this essay, the first mistake is that traditional RCR pedagogy neglects an important opportunity to enable scientists to understand and appreciate the full range of ethical issues relevant to research in the sciences. The second mistake is that the BIC itself is not achieving its

[1] The second merit criterion emphasized components of the original Criterion Three: Utility and Relevance of Research, and Criterion Four: Effect on Infrastructure of Science and Engineering; with two new concerns, namely, i) broadening the participation of underrepresented groups and ii) promoting teaching, training, and learning.

full potential because scientists and social scientists are not provided the knowledge and skills they need in current training in Research Ethics to fully appreciate the nature and value of broader impacts.

The limitations of traditional RCR training are all the more worrisome as Universities across the nation gear up to respond to the America COMPETES Act. Passed in August, 2007, the America Creating Opportunities to Meaningfully Provide Excellence in Technology, Education, and Science Act, 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.

One of the provisions of this act, Section 7009, requires that the National Science Foundation ensure 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." As Universities develop plans to respond to America COMPETES, it is essential that they base the content of these courses, workshops, and the like upon a robust model of research ethics. This need is clearly reflected in the NSF's perception of the value and function of this Act. "Ethics education is particularly critical to the science and engineering community as it faces an increasingly competitive funding environment; rising collaboration with international colleagues who may follow different guidelines; and growing recognition of the relevance of science and engineering to social, economic, and ethical issues of wide public and political interest."[2] Traditional RCR training does not provide scientists the resources that they need to be able to respond to the NSF's understanding of what Section 7009 requires in that it does not include the broader impacts of science, that is it does not provide training in the ethical issues arising from the relationship between science and society.

To fully respond to America COMPETES, we believe that the traditional model of research ethics will have to be expanded to include such issues as the NSF lists in the above quote. Although our emphasis in this paper will be on the importance of including training in the BIC in research ethics curriculum, in the next section we introduce a model of research ethics that reflects this needed expansion. We have labeled this broader conception of ethics training the Ethical Dimensions of Scientific Research (EDSR), and urge that Universities in the U.S. adopt this model as they respond to America COMPETES.

3. The Ethical Dimensions of Scientific Research—Development of the Model

The inspiration for EDSR emerged from an NSF Ethics in Engineering and Science Education (EESE) funded[3] three-year intra-institutional collaboration between faculty in the environmental

[2] "Status Update on NSF Implementation of Section 7009 of the America COMPETES Act (ACA): Responsible Conduct of Research Advisory Committee for Business and Operations Spring Meeting, May 29-30, 2008"

[3] We would like to acknowledge the generous support of the US National Science Foundation for providing funding

and economic sciences, ethicists, science and technology studies scholars, and education specialists working in the area of responsible conduct of research pedagogy.[4] The two main hypotheses of the study were a) augmenting traditional RCR curriculum with additional ethics modules designed to identify ethical issues as they appeared within the context of scientific research and practice would improve[5] graduate student understanding of and attitudes toward research ethics and b) research ethics curricula designed in close consultation with and taught by science faculty within the context of their courses would improve research ethics content and pedagogy. The hypothesis most relevant to this paper is the second hypothesis, which will be our focus. For information on our findings regarding the first hypothesis, see forthcoming papers by Schienke at al, "Educational Impacts on Learning Responsible Conduct of Research Principles: an Assessment of Graduate Students in the Environmental Sciences," and "Qualitative Changes in Attitudes towards Responsible Conduct of Research: an Assessment of Educational Interventions on Graduate Students in the Environmental Sciences."

Our research approach required the direct participation of science faculty, both in the teaching of basic RCR principles and in the production of new ethics content. The research group (of eight to ten) met regularly, (every other month for the first year-and-a-half of the project to once a semester later in the project) to report on recent progress, evaluate ethics content development, and provide feedback from the various disciplines represented. Group meetings were an integral aspect of the project as the meetings provided a forum for learning and communication between disciplines (such as ethics and economics) and for critical review and refinement of the ethics content being developed as curricular modules.

The research group developed ten curricular modules[6] based on examples derived from the field of practice, e.g. from published papers, well-established theories and techniques, and examples of scientific research being used in policy contexts, for use in graduate classes in the environmental sciences. The group agreed to develop modules across six general themes that frequently involve ethical decision-making in the environmental sciences: responsible conduct of research; data analysis; sustainability; cost/benefit analysis; environmental risk-analysis; and decision-making under uncertainty. Each module is comprised of presentation slides, an instructor's manual, and readings that support the case. While the modules were developed using examples drawn from the specific content being taught by our scientific faculty, the modules are

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[4] This constellation/pool of specialties is not present in most institutions and has thus provided a novel context for this research to take place.

[5] Improvement in this case is described in two papers reporting on the research findings from the study which included the development, piloting, and running of instruments (a total of n=97 students completed the pre module assessments and n=33 completed both the pre and post module assessments) that assessed for improvements in students' performance on a knowledge-based RCR instrument (twenty-five questions scored as either correct or wrong) and an instrument assessing attitudes towards research ethics (ten questions with a scale of 1-5 as to whether the situation was unethical or ethical alongside qualitative written answers explaining their reasoning).

[6] Seven of the ten modules are published and the modules and instructor manuals are available online at: http://rockethics.psu.edu/education/environment/nsf.shtml Two of the modules are still in development and one module was excluded after peer review

designed so that other faculty can adapt a module to their courses using new cases or examples chosen to match the course content while retaining the ethical discussion of issues. The key ethical considerations addressed by the modules include overconfidence of model projections, potential impacts of errors in data analysis, formulation of the null hypothesis (falsifiability), ethical issues embedded in cost/benefit analyses, or the determination of whether or not one has sufficient data to make valid claims.

Our project demonstrated that RCR education as typically taught neglects many ethical issues deeply embedded in research design, treatment of uncertainty, issues of overconfidence, and the like. These were ethical issues that we came to label as "intrinsic" to scientific research. However, through the extensive inter-disciplinary ethical discussions and module development process, we discovered that there were other important ethical issues typically overlooked by RCR training that were of a different category than those embedded in research design. These involved the broader impacts of the research, or what we labeled "extrinsic" issues. We came to appreciate that for Research Ethics training to be adequate to the goals of the America COMPETES act, RCR training must be augmented with two additional, often overlapping, components of research ethics.

These insights led to the development of a new model of research ethics that is one of the most significant outcomes of our collaboration. This new model identifies three separate though often intersecting components of ethics in science -- procedural ethics (RCR), intrinsic ethics (contextually specific), and extrinsic ethics (broader impacts).[7] This model, which we have labeled the Ethical Dimensions of Scientific Research (EDSR), is detailed in Section 3 and Figure I.

4. From RCR to the Ethical Dimensions of Scientific Research (EDSR)

Our research project was influenced by a number of studies that found RCR instruction to be minimally effective in the context of biomedical curricula [4-7]. This finding is particularly troubling in that at the same time that studies call attention to the ineffectiveness of RCR education, lead agencies insist on the importance of training in research ethics and argue that it is "central to conducting good science" (p. 9) [8]. As early as 1989, the Institute of Medicine report *The Responsible Conduct of Research in the Health Sciences* proposed "Universities should provide formal instruction in good research practices. This instruction should not be limited to formal courses but should be incorporated into various places in the undergraduate and graduate curricula for all science students" (p. 30) [9]. In 1995, the *Report on the Commission on Research Integrity* argued for the "integration of the explicit teaching of the ethics of science into the classroom, laboratory, and other research sites in precollegiate education as well as in undergraduate and graduate schools" (p. 25) [10]. In addition, the National Science Foundation, through their Office of Inspector General, promotes and runs extensive educational seminars on a wide variety of research misconduct topics as an integral part of outreach to "provide education to our grantees so they can prevent problems that otherwise might lead to an OIG investigation"

[7] The terms procedural, extrinsic, and intrinsic are being used here in a manner that is specific to the EDSR model. Procedural ethics in this case refers to proper conduct of research in a laboratory and is not intended to link to a broader conception of procedural justice.

[11]. However, *education on the Broader Impacts Criterion (BIC) is missing from the extensive list of NSF OIG RCR outreach efforts*.

Anderson [12] and Kalichman [13] attribute the above noted ineffectiveness of RCR instruction to the context in which it is disseminated, noting that it is often the responsibility of non-scientists who lack authority or credibility with those being taught. This, however, is not the model proposed by most agencies. For example, the 2002 *Institute of Medicine Report on Research Integrity* recommended "…placing the education in the context of the research instead of making it a separate entity" (p. 10) and "The instruction should be provided as much as possible by faculty who are actively engaged in research related to that of the trainees" (p. 86) [14]. Science faculty, however, are often ill-prepared to offer effective training in research ethics and little has been done to provide them with effective pedagogical strategies.

Recognizing such concerns, we worked to create an ethics education paradigm that i) science faculty would see as intimately relevant to their research, ii) was linked directly to the specific content of their classes, and iii) offers pedagogical materials and strategies to easily and effectively incorporate ethics into classes and lab settings. These various goals aim to ensure that science faculty would become strong advocates of the importance of such training.

It was in the process of working towards these goals that we recognized that RCR, while important, did not cover the full range of ethical aspects of scientific inquiry. RCR is particularly inadequate when ethical issues arise from specific scientific content or from the implications of scientific knowledge. In response to these inadequacies, we propose the recognition of three distinct components of science research ethics.

1) **Procedural ethics**: ethical aspects of the process of conducting scientific research, 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 [15-17].

2) **Intrinsic ethics**: ethical issues intrinsic to the production of scientific research, i.e. ethical issues embedded in the research, such as: the use of certain equations, constants, and variables; analysis of data; handling of error and degree of confidence in projections; and choice of a cost-benefit analysis paradigm.[8]

3) **Extrinsic ethics**: ethical issues extrinsic to the production of scientific research, i.e. ethical issues in how the outcomes of science research impact society, such as: policy making; lawsuits; changes in social norms; and education and entertainment.

[8] For a full discussion of intrinsic ethics see the forthcoming paper Schienke et al "The Intrinsic Approach to Teaching Ethics to Graduate Students in the Environmental Sciences: the Case of Discounting in Climate Change Policy."

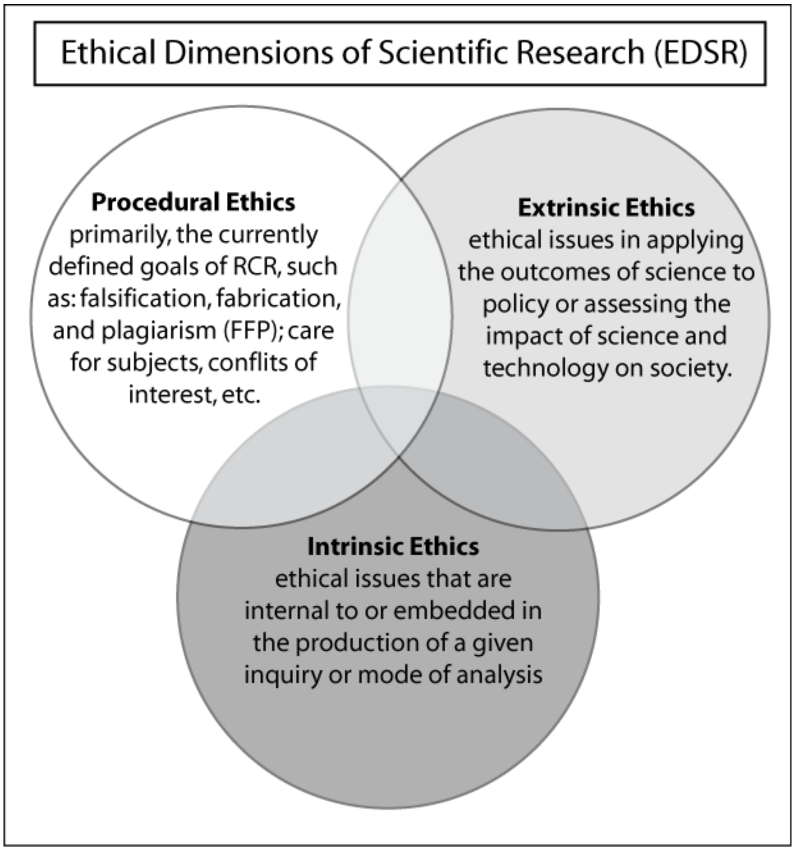

Figure I. Domain diagram of the Ethical Dimensions of Scientific Research model of a broader conception of "research ethics."

These three components comprise a new model of research ethics, the Ethical Dimensions of Scientific Research (EDSR) that we advocate as a successor to RCR pedagogical approaches to research ethics. Using this new model, we worked to produce pedagogical materials that aptly addressed all three of these dimensions. As we began to develop modules that would provide instruction on extrinsic ethics, it became clear to us that *the goals of extrinsic ethics corresponded directly with the fundamental intent of the NSF Broader Impacts Criterion* (BIC).

Although the remainder of the essay will focus on the claim that BIC is an essential component of extrinsic ethics within the EDSR, our underlying position is that all three dimensions must be included within research ethics training to establish an effective and comprehensive approach to EDSR.

5. Problems in the uptake and education of BIC

Somewhat parallel to the concerns about the effectiveness of RCR education are concerns about the impact of the BIC. The National Academy of Public Administration (NAPA) was hired in 2001 to conduct an audit for the NSF assessing how well the merit criteria were being applied [18]. The report concluded that reviewers were largely ignoring the BIC, and when it was considered it was only considered after the cutoff was applied via "intellectual merit" of a given proposal [19]. Further, the marginalization of the BIC had gotten to the point that proposals and reviewers were hardly addressing it and, in some cases, leaving it out entirely. In response, the NSF released Important Notice No. 127, which stated to the STEM community that "effective October 1, 2002, NSF will return without review proposals that do not separately address both merit review criteria within the Project Summary. We believe that these changes to NSF proposal preparation and processing guidelines will more clearly articulate the importance of broader impacts to NSF funded projects" [20].

Through informal responses solicited when piloting the BIC module and through interviews with the scientists on our project that drew from their experience as NSF review panelists, we noticed the following about how the BIC is understood and approached.[9] 1) Some scientists consider BIC to be irrelevant to the research being conducted. 2) Some scientists responded that BIC is rather easy to argue if they are conducting research relevant to decision-making and public policy, such as research on climate change, but that this applied to a narrow range of scientific inquiry. 3) Many scientists find it difficult to argue for the significance of the BIC to improving science and scientific knowledge and do not have the terminology of BIC issues close at hand. 4) Some scientists commented that they have no specific training whatsoever in interpreting BIC and that what sense it makes to them is due to non-science components of their education. 5) A common response was that whether they are playing the role of either a reviewer or submitter, the BIC is the least important aspect of an NSF proposal. 6) Finally, our interviewees indicated that their attitudes toward the BIC improved once the goals of the BIC were more clearly articulated to them within the context of a specific research proposal or if they have partnered with co-PIs who are able to address education outreach and broader social impacts.

Based on the results of our interviews as well extending from what was learned in the development of our own BIC educational materials, we agree with the conclusion of Holbrook and Frodeman that "reacting to BIC with confusion or resistance is due not only to the fact that most scientists and engineers are trained in how to conduct research with strong "intellectual merit" and are not trained in how to address the "broader impacts" of their research [21]. It is also that too few basic researchers are taught to ask, much less to answer, the more philosophical question as to *why* the "broader impacts" of their research are important" [22].

It is our contention that the single biggest factor hindering the uptake of BIC in proposals and reviews is proper education on both the basic concepts of BIC and *the ethical principles upon which it is based*. To address this shortcoming, we recommend: 1) that BIC educational materials be integrated into research ethics training programs and 2) that BIC core concepts be further integrated into the science classroom, particularly at the level of graduate training and postdoctoral professionalization. To contribute to this endeavor, in the remainder of this essay we offer an analysis of the ethical significance of the BIC.

6. BIC as an Essential Component of EDSR – Learning from the Example of Climate

[9] We received verbal feedback from eleven participants to the piloting of the module at a workshop. We conducted in-depth debriefing interviews with three of the research scientists involved. However, we can make no claim as to the representativeness of our sample of pilot participants and interviewees. These are simply responses collected across the sample.

Change Research

Scientific research has both direct and indirect impacts upon many dimensions of society [23-36]. Since a research topic that unites the scientists on our team is global climate change, the broader impacts of climate change research were a natural consideration for our group. Several ethical considerations related to BIC were identified.

1) Distributive justice: The benefits and harms of global climate change, for example, are not equally distributed across space; likewise, those most responsible for the anthropogenic components of climate change often do not bear the largest burden of harms from climate impacts.

2) Intergenerational justice: current and past greenhouse gas emissions and other climate-relevant decisions (such as how to adapt to climatic changes) will impact future generations.

3) Social impact: Research on global climate change often has direct relevance to policy and other decisions; how the research is conducted and presented can be quite influential to these decisions.

The team thus analyzed how we might best help scientists provide training in the ethical dimensions of these issues. In particular, we wanted our modules to provide an appreciation and understanding of what happens to scientific research as it: 1) informs decision making; 2) improves social capacity to confront uncertainty and risk; 3) impacts issues relevant to principles of justice and equity; and, 4) engages questions of pressing concern to society.

We realized that one of the most effective ways of addressing issues such as social capacity, questions of justice, or the link between scientific research and adequate policy development would be through a module devoted to the NSF's Broader Impacts Criteria (BIC). We also came to the conclusion that training on the ethical dimensions of the BIC would not only enhance EDSR education, but that by including it in EDSR education, the BIC itself would be better understood, appreciated, and implemented by scientists.

The ethics module that we discuss in the next section provides this needed training.

7. Extrinsic Ethics and the BIC

The BIC module presents a model of "quality science" that involves two elements: i) "responsible scientific practice" (intellectual merit, capacity to conduct research, qualifications of organization, and conception of research question) and ii) inquiry that is *responsive* to broader considerations both within the scientific community as well as to the broader society (civic relevancy, representation of diversity and underrepresented groups, value to society, and capacity building).

The module illustrates links between three key elements of ethics not covered by RCR, namely distributive justice, procedural justice, and intergenerational justice, and the five components of the BIC. The purpose for mapping the ethical issues in such a manner is to illustrate the full ethical dimensions of the BIC and provide a way for understanding how the principles of BIC extend from the larger goals of social justice — principles that are and ought to be the foundation of all publicly funded projects. Thus, the NSF's two merit criteria, when properly applied, are designed to support scientific inquiry that is both intellectually responsible and socially responsive. It is the goal of our module to assist future generations of scientists and social scientists in understanding the underlying ethical dimensions of the BIC.

Although we do not claim that our examination of the ethical issues and values relevant to the BIC is exhaustive, we believe that this analysis provides a solid foundation for this topic and will encourage a rich dialogue about the ethical dimensions of this criterion. We would also stress that the BIC does not represent the entire range of *extrinsic ethic*s issues included within the EDSR model, which also includes such topics as the responsible use of research and ethical decisions regarding research-funding sources.[10]

In the remainder of this essay, it is our goal to outline some of the ethical foundations of the BIC that would enrich training on the topic of research ethics.

a. Distributive Justice: allocation of benefits and burdens of an activity

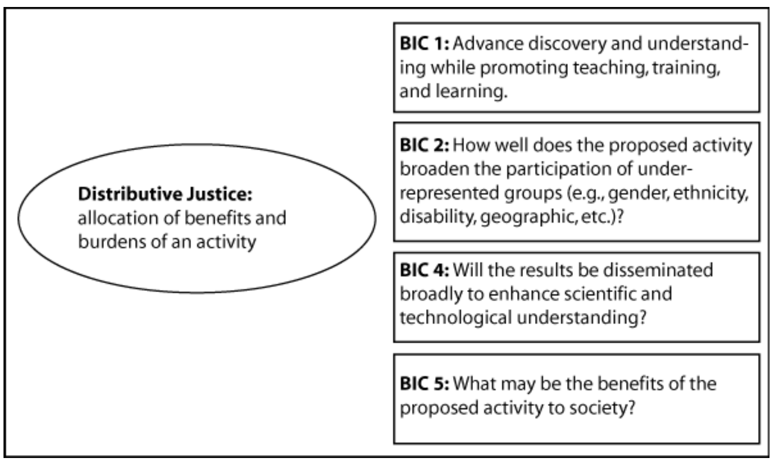

Figure II. Distributive Justice aspects of the Broader Impacts Criterion.

The normative principles of distributive justice provide strategies for determining how the benefits and burdens of a particular activity ought to be allocated across various sectors of society. Approaches to distributive justice that are most fitting to the above BIC components are strict egalitarianism, John Rawls' Difference Principle, and utility maximization. Strict egalitarianism and related principles of resource-based egalitarianism suggest that resources, whether it be in terms of availability of scientific training or in terms of the impacts of the outcomes of a research project, be spread evenly across all sectors of society [37-39]. The Rawlsian Difference Principle would require that any differences in distribution are acceptable only if they are to the greatest benefit of the least-advantaged members of society and there is fair equality of opportunity [26]. Utilitarianism, a framework that is often the focus of cost-

[10] Although in introducing our model of the ethical dimensions of scientific research we separated intrinsic ethics and extrinsic ethics to clarify and illustrate these concepts, we recognize that in some instances intrinsic and extrinsic ethical issues overlap – hence the use of a Venn Diagram. Topics such as the responsible use of research can involve all three aspects of the ethical dimensions of scientific research.

benefit analyses, would require that the overall benefit to society is maximized [41-44].

Other approaches to distributive justice, such as desert-based principles of allocation [45-46] based on overall merit, are relevant both to the overall review process in the ranking of both the Intellectual Merit and the Broader Impacts Criteria. It is important to recognize, however, that the BIC does not emphasize one mode of distributive justice over another, such as strict resource-based outcomes over welfare-based outcomes, but that certain subcriteria of BIC do speak, as we will outline below, more directly to egalitarian outcomes while other subcriteria address improving the conditions of the least-advantaged sectors of society.

BIC 1: Advance discovery and understanding while promoting teaching, training, and learning. This criterion follows from distributive justice principles of egalitarianism. Here the goal of translating research into educational opportunities is aimed at improving teaching, training and learning at all levels of education. That is, developing a research program that provides for "innovative connections between research and educational opportunities that engage, excite, recruit, and retain students at all levels, from K-12 to junior faculty" would likely result in improving science education and appreciation across many levels of society. Here the goal is to better distribute a good—in this case access to science education—across all members of society.

The flip side of this issue is to note that advancing discovery and understanding itself has the potential to benefit society. The ethical challenge here can thus involve how to best balance these normative goals.

BIC 4: Broaden dissemination to enhance scientific and technological understanding. The NSF similarly frames this criterion around distributive justice principles of egalitarianism. Here the goals are to enhance opportunities for scientists to learn from and/or collaborate with peers (e.g., “forging links to other scientific disciplines,” “sharing of data that might not otherwise be easily accessible”) to more broadly propagating an understanding and appreciation of scientific and technological developments (e.g. “assisting journalists with their stories” or “creating materials for research related websites enhanced by engaging animations and movies to educate non-scientists and the public at large”).

Here we note that other normative concerns could also be relevant, such as the value of enhancing deliberative democracy through broadened dissemination of scientific and technological understanding. We do not claim that a justice perspective is the sole normative framework relevant to the BIC and urge scholars to join us in identifying and analyzing the ethical dimensions of the BIC.

BIC 2: Broadening participation of underrepresented groups. This follows from a distributive justice commitment in line with Rawls' Difference Principle, in which outcomes are to be to the greatest benefit of the least advantaged members of society [47]. Here the BIC goal of "broadening participation of underrepresented groups," particularly in "providing scientific training for members of underrepresented groups to diversify the disciplines of science," can be understood to be based on a social justice perspective of actively enhancing the participation of groups that had previously been less able to so participate. Hence, one way to interpret this component of the BIC is to appreciate that it is an element in bringing about more fair access to a good, in this case science and engineering education. This goal, in turn, is then seen as a key factor in achieving another goal, namely excellence in discovery and innovation in science and engineering. The National Science Board's *The Science and Engineering Workforce: Realizing America's Potential* argues, for example, that this goal requires "an ample and well-educated workforce" that in turn requires interventions "to improve success in educating S&E students from all demographic groups, especially those that have been underrepresented in S&E careers." Hence, a social justice component is here seen as linked to a greater good outcome.

Another way to understand BIC 2 is to see it as not only advocating "scientific training" for underrepresented groups, but also recognizing that the participation of underrepresented groups may have epistemological benefits, for example, through addressing perspectives, experiences, or interests that had previously been overlooked or discounted perhaps because of the same dynamics that accounts for the under-representation of the groups themselves. In those instances where scientific research is so enhanced, promoting the participation of underrepresented groups can be seen as not only augmenting the BIC but also the intellectual merit of the research [48].

BIC 5: Arguing how proposed research "provides benefits to society" asks scientists to consider how their research impacts society, in particular who it benefits and how. The NSF has specifically requested that, "emphasis should be wherever and whenever appropriate on technological advances that will profit our economy, benefit our health and increase our national security." Here the NSF has introduced a normative dimension concerning which benefits are most desirable. We add to this the examination of additional normative elements, such as how the benefits of scientific research should be distributed across sectors of society as well as whether questions of environmental justice are also relevant. And here again we see the relevance of questions regarding distributive justice. That is, should benefits be enhanced regardless of distribution or should distribution of benefits be structured with attention to differential needs? Neither the NSF nor we advocate one form of distributive justice over the other. But this component of the BIC calls on scientists to seriously address how they believe the benefits of their research *should* be distributed and thus engage in normative reflection.

We also note that while this component of the BIC focuses on benefits to society, it is also important to consider potential harms of research and to apply the same principles of distributive justice to such considerations. That is, in proposed research, are possible harms to groups, society, or the environment clearly identified? If there are such harms, then ethical analysis is relevant from a variety of perspectives. Consider, for example, fair distribution of potential harms. Do the possible harms disproportionately impact certain populations or are they equitably distributed across all sectors of society? If the possible harms fall heavily on one sector, group, demographic, class, gender, or ethnicity, is it possible to justify putting that group at risk or should the research be reconsidered?

Although we cannot address in depth these issues or detail the entirety of the issues of distributive justice entailed by the BIC, we hope that the links between distributive justice and the BIC have been made sufficiently clear to warrant careful attention to training in these issues in the course of training in research ethics.

β. Procedural Justice: Enhancing the participation of groups in the process through which research decisions are made and results are disseminated so more have access to research processes and outcomes

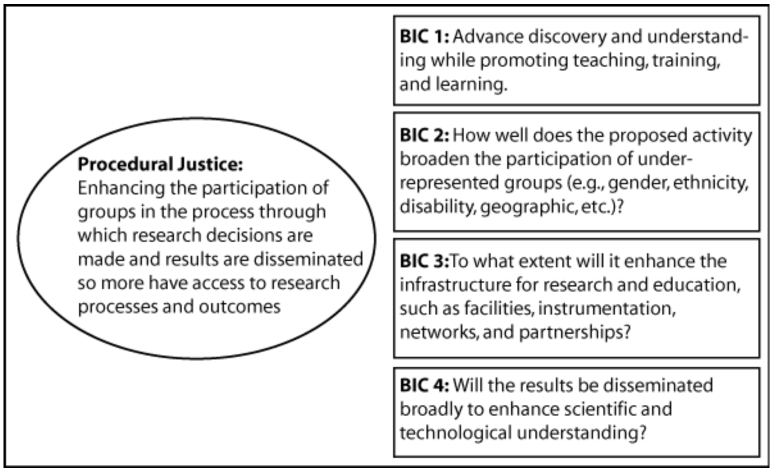

Figure III. Procedural Justice aspects of the Broader Impacts Criterion.

Procedural justice issues are related to the legal principles of due process and equal access to the law and legal system. There are a variety of models of procedural justice that could inform our interpretation of the BIC. The outcomes model asserts that procedural fairness depends on the order and context of procedure to determine fair outcomes [49]. The accuracy model is concerned with ensuring the law itself is accurately applied to the facts [50]. The balancing model holds that the benefits of the outcomes should be commensurate with the costs of the procedure itself [50]. That is, the cost of accessing and implementing proper procedure should not be costlier than the outcomes of the procedure. Fourth, the participation model requires that accommodations be made to ensure that those affected by a decision have access to participation in the decision-making process [47]. While all of these models are not necessarily relevant to interpreting the BIC, they provide a basis for understanding the ethical principles that underlie it. Here we outline some of these.

There are aspects of procedural justice embedded in the BIC through its efforts to 1) broaden participation in scientific processes themselves (BIC 1 and 2), and 2) broaden participation in scientific literacy (BIC 4).

BIC 1: Broadening participation in scientific processes would arguably produce publicly funded scientific research that was both more diverse and representative of a broader set of interests. Again, moving to broaden participation in scientific process and procedure speaks to the goals of producing both a more responsible and responsive science.

BIC 2: The BIC goal of increasing the participation of underrepresented groups would also address the procedural justice goal of enhancing the participation of underrepresented groups in both the practice of science and in the design of research questions. This category, combined with BIC 3, “to enhance infrastructure for research and education,” could serve to improve research capacity at historically black colleges and other colleges that serve underrepresented groups. BIC 2 also entails working to ensure proper and representative access to the application and review processes.

Broadening the participation of underrepresented groups in the design of research questions can be a component of procedural justice considerations. In areas of science where the interests and needs of certain groups have been ignored or obscured, the inclusion of underrepresented groups into the scientific progress is required not only by distributive justice concerns, but also from procedural justice concerns.

BIC 4: Broaden dissemination to enhance scientific and technological understanding addresses the need to enhance the informed participation of the non-scientific community, say in policy formation relevant to or involving science and technology through scientific literacy. An informed and scientifically literate population is better able to actively and responsibly participate in such decisions, whether at the local or global level.

This is a both a short term issue, in that sometimes provisions could be made in a proposal to ensure that policy relevant scientific research will also take efforts to coherently communicate research findings to the relevant users of such information. And it is a long term issue, in that provisions need to be made in research projects to ensure new scientific findings are being communicated at all levels of scientific literacy, from K-12 to junior faculty. Improving the education and communication of findings will likely improve not only understanding of research findings, but also work to provide the intellectual capacity for underrepresented groups to seek funding in the future.

χ. **Intergenerational Justice: the duty of present generations not to pursue policies or practices that create benefits for present subjects while imposing costs or harms on those who will live in the future**

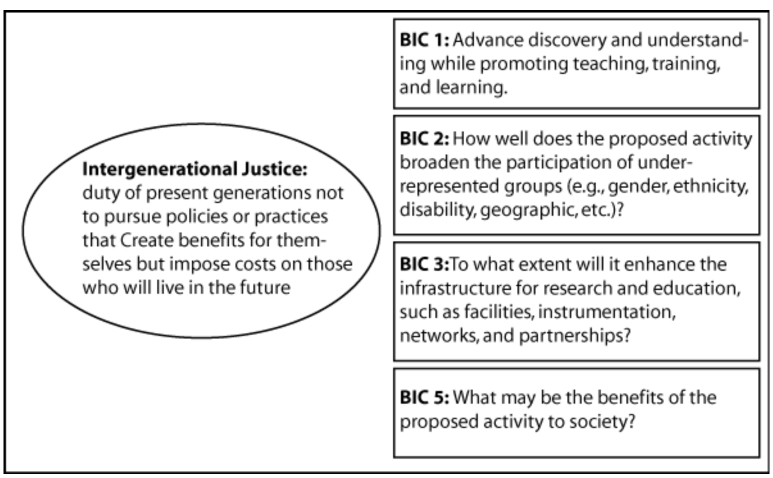

Figure IV. Intergenerational Justice aspects of the Broader Impacts Criterion.

Decisions made in the present can positively or adversely affect the lives of individuals and populations in the future, just as the cumulative decisions of past generations have determined many of our current conditions. Choices made now, particularly in the path of scientific and technological research, can have significant impacts on future conditions for generations to come. The impact of present generations with respect to future generations that can give rise to duties required by intergenerational justice have been categorized in the following way: 1) the choices of current generations regarding present investments in research projects or infrastructural choices can impact how future generations will be required to spend resources in order to continue along the same path of development because of needs or expectations created by present investments; 2) current generations can harm future generations through choices made about resource consumption or other actions that create less favorable future circumstances; 3) choices made now can effect whether or not humans exist in the future, how many humans will exist, and who will exist; and 4) since there are deep uncertainties about future states, how we calculate these uncertainties can directly and negatively impact how we manage risk, use resources, and plan for possible negative outcomes.

Climate change, for example, raises significant intergenerational justice concerns in all four of these ways. However there are numerous arenas of scientific and technological research that involve significant intergenerational justice issues, hence training around this issue is a key element of training in EDSR. One avenue to such training is the BIC as we discuss below. Since broader impacts include impacts on future generations, intergenerational justice issues can be seen as an important lens for many of the BIC components.

BIC 1 & 3: Advance discovery and understanding while promoting teaching, training, and learning and enhance infrastructure for research and education. Moving scientific and technological research forward is the primary purpose of the NSF and, in this regard, it can be said that all proposals funded are in some way or another concerned with improving future outcomes under the BIC goal of enhancing infrastructure for research and education (BIC 3). While it is difficult to project specific future outcomes from particular research trajectories, we can with higher confidence positively impact future conditions through measures such as enhancing infrastructure or improving educational opportunities. The first BIC directive to "advance discovery and understanding while promoting teaching, training, and learning," (BIC 1) thus rests upon such a foundation.

Building infrastructure and promoting training and teaching ensures that a community of scientific or technological practice will exist in the future to capitalize on current research investments and thus explains the NSF BIC efforts to provide educational opportunities from K-12 through to junior faculty. This is, in the words of the National Science Board, how we "realize America's potential" in the future. "The Federal Government has a primary responsibility to lead the Nation in developing and implementing a coordinated, effective response to our long-term needs for science and engineering skills. US global leadership and future national prosperity and security depend on meeting this challenge" (p. 42) [51].

BIC 2: Broaden participation of underrepresented groups. While ensuring educational opportunities that will provide the conditions and infrastructure for intellectual capacity for future generations, further broadening the participation of underrepresented groups now ensures their increased participation in the future. Improving diversity and active participation of underrepresented populations in the future production of science–such as women, African Americans, American Indians including Native Alaskans, Hispanics, Native Pacific Islanders, and persons with disabilities–requires being vigilant about including their participation in the present configurations of scientific research and training. This includes ensuring participation of underrepresented groups in current research collaborations, formulating research hypothesis to include the interests and concerns of underrepresented groups, and taking extra measures to provide educational opportunities in terms of content and infrastructure to underrepresented communities.

BIC 5: Provide benefits to society. The BIC directive of providing benefits to society cannot be seen as referring only to benefits to current society, since we want the benefits to be long-lasting. Hence, this component of the BIC requires understanding and considering issues of intergenerational justice and examining how the proposed research impacts future generations.

While we do not claim that the question of future impact is simple, we stress the importance of attending to time spans and to take into account how far into the future considerations are being made, an issue which is dependent on the context of the specific research. For example, some research and infrastructure choices can lead to short and medium term benefits while producing longer-term harms. As such, it is important to distinguish the time span of benefits and harms and work to determine or project a temporal threshold in measuring benefits or harms.

The BIC thus brings intergenerational justice perspectives into consideration, asking that researchers consider training and infrastructure development that best supports the robust and full participation of a broad range of future generations–both near term and in the more remote future. Similarly, research should be designed so that benefits or risks are equitable to future generations and research commitments attentive to the impact to future generations so that they are not unfairly burdened by the need to spend resources and finances to continue along the same path of development.

8. Conclusions

Expanding research ethics beyond the procedural concerns of RCR includes considerations regarding how research broadly impacts society. We argue that the five subsections of the NSF BIC can successfully provide this component of the ethical dimensions of scientific research (EDSR). We claim that including training on the BIC and the ethical foundations of the BIC within research ethics pedagogy will positively impact the performance of the BIC in proposal submissions and reviews.

We contend that teaching about the ethical dimensions in the BIC and using BIC pedagogically in conjunction with RCR training can i) improve the inclusion of and capacity to review for BIC in NSF proposals and ii) enhance research ethics training by providing a more comprehensive understanding of the ethics relevant to scientific research. We recommend that the BIC and its underlying ethical foundations be better integrated into the training of all research scientists, and become a robust component of Research Ethics training as Universities respond to America COMPETES.

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