# AC 2009-1131: INTEGRATING MICROETHICS AND MACROETHICS IN GRADUATE SCIENCE AND ENGINEERING EDUCATION: DEVELOPING INSTRUCTIONAL MODELS

**Joseph Herkert, Arizona State University Polytechnic**

Joseph Herkert, D. Sc., P.E., is Lincoln Associate Professor of Ethics and Technology at Arizona State University. He has taught engineering ethics and related courses for more than twenty years. His work on engineering ethics has appeared in engineering, law, social science, and applied ethics journals. Dr. Herkert is the past Editor of IEEE Technology & Society and a founding Associate Editor of Engineering Studies. He received his BSEE from Southern Methodist University and his doctorate in Engineering and Policy from Washington University in St. Louis. He has been honored for his contributions by the ASEE Liberal Education Division and the IEEE Society on Social Implications of Technology.

**Jameson Wetmore, Arizona State University**

Jameson Wetmore is an assistant professor in the School of Human Evolution & Social Change and the Consortium for Science, Policy & Outcomes at Arizona State University. He has a PhD in Science & Technology Studies from Cornell University. He studies the social dimensions of technology with particular interests in regulation, social implications, and the development of new ways to help scientists and engineers understand their impacts on and responsibilities to the world. He recently edited two volumes: Technology & Society: Building Our Sociotechnical Future (MIT Press) and the Yearbook of Nanotechnology in Society, Volume 1: Presenting Futures (Springer).

**Heather Canary, Arizona State University Polytechnic**

Heather E. Canary (PhD, Arizona State University, 2007) is assistant professor of communication at Arizona State University. Her primary research areas include organizational communication and family communication in contexts of disability and public policy. She teaches courses across the communication discipline, particularly in organizational and family communication. In her courses, Dr. Canary emphasizes ethical implications of communication behavior. Her research includes investigating efficacy of ethics education in communication courses. Dr. Canary's work has been published in several journals, including Journal of Business Ethics, Communication Education, Journal of Applied Communication Research, and Health Communication.

**Karin Ellison, Arizona State University**

Dr. Ellison works in the areas of research ethics and history of technology. As Associate Director, Center for Biology at Society, she provides responsible conduct of research education to life scientists and is a founding member the doctoral degree program in science studies. As a Dean's Fellow, she is reviewing the student academic integrity policy for the College of Liberal Arts and Sciences. Prior to coming to ASU, Dr. Ellison was Interim Assistant Dean for Research Policy and Compliance at the University of Wisconsin-Madison. Dr. Ellison's Ph.D. is from the Program in Science, Technology and Society at MIT.

# Integrating Microethics and Macroethics in Graduate Science and Engineering Education: Developing Instructional Models

While the government and the public look to universities to educate students in research ethics[1,2,3], those who teach ethics to science and engineering graduate students still struggle to find the most effective models for ensuring that their students internalize professional values and make them part of their scientific and technical practices[4,5,6]. This paper will report on the first stage of a three year NSF-funded research project to develop and assess four different instructional models that introduce and educate science and engineering graduate students to the microethical and macroethical issues in their work.

Graduate education in science and engineering ethics has typically focused on responsible conduct in research (RCR) issues and has had a microethical focus (although collective responsibilities are sometimes explored). Topics such as public policy on stem cell research or the societal implications of emerging technologies, on the other hand, generally fall within the realm of macroethics. "Microethics" refers to moral dilemmas and issues confronting individual researchers or practitioners, whereas "macroethics" refers to moral dilemmas and issues that collectively confront the scientific enterprise or the engineering profession, as well as societal decisions about science and technology[7]. Microethical issues in engineering practice include such topics as health & safety and bribes & gifts, while macroethical issues include such topics as sustainable development and privacy concerns posed by emerging information and communication technologies. Similarly, microethical issues in scientific research include, for example, research integrity and fair credit; macroethical issues include challenges to personal identity posed by such technologies as human cloning and artificial intelligence

The importance of macroethics in science and engineering has gained wider appreciation in recent years, especially in connection with emerging technologies such as nanotechnology, biotechnology, and advanced information and communication technology[8]. Ethics and science & technology studies scholars alike have begun to note the importance of including both micro- and macroethics in technical education[9,10,11]. In terms of course development, however, efforts at integrating micro- and macroethics in graduate education of engineers and scientists have been few[12,13].

This project's goals are to: 1) formulate educational outcomes for the integration of micro- and macroethics in graduate science and engineering education; 2) develop and pilot different models for teaching micro- and macroethics to graduate students in science and engineering; 3) assess the comparative effectiveness of the instructional models; 4) facilitate adoption of the instructional models and assessment methods at other academic institutions; and 5) provide for widespread dissemination of course materials and assessment results in the engineering, science, and ethics education communities. The project has four components: a Coordination Workshop; development of four instructional models for integrating micro- and macroethics in graduate science and engineering education; comprehensive project assessment; and a Results Dissemination Workshop. The project team includes ethics, science, engineering, science & technology studies, and communication faculty at two campuses of Arizona State University

(ASU), an Advisory Council of faculty from four other universities; and three consultants with national reputations in science and engineering ethics education.

## Instructional Models

An important premise of the project is that new modes of teaching will be necessary because in order for these efforts to be successful scientists and engineers cannot simply learn about ethics, but must incorporate new perspectives into their daily practice and professional behavior. The four models included in the project are: 1) a stand alone course on societal implications of science and engineering; 2) micro- and macroethics material embedded in a required science course; 3) online instructional modules; and 4) engaging ethics in the lab.

*Model 1 – Stand Alone Course*

Many undergraduate science and engineering programs offer stand alone courses in technical ethics, but they are rare at the graduate level. Because of this we developed a number of strategies to attract graduate students to a course covering micro- and macroethics.

Initially we had hoped to offer a three credit course that would engage scientist and engineer students. What we've found, however, is that it is difficult for a large number of students to justify, either to themselves or to their advisors, a time consuming course that will not likely help them advance toward their degree. While a select few students are willing to fight the system to enroll in such a course, we decided to make sure that a larger number can participate and instead created a one credit course.

The most obvious advantage is the smaller time commitment than a three credit course. This works for both the students and the faculty. The students would be hesitant to overload with an extra three credits a semester, but a one credit course limits the time commitment and thereby increases the likelihood of enrollment. For the faculty it means that the course can be taught every semester with only minimal impingement on their regular teaching load. The increase in offerings makes it possible for students who have other commitments to at least occasionally enroll in the course.

We were also able to increase enrollment by negotiating with the Chemistry department to allow the course to meet its mandatory CHM 501 (current topics in chemistry) requirement. Because CHM 501 is usually a series of unrelated presentations by students, by and large it is not well liked. Students were eager to take an alternative course.

Because we can offer it every semester we have decided to rotate the topics presented. In one semester we might do a broad overview of science policy and the macroethical issues it raises while in another semester we might focus on the responsibility and skill necessary to communicate science to the public. Different students have different interests and can be drawn in by different topics.

To further make sure that we are covering topics of interest to the students, and thereby motivate them to more fully participate in class and reflect on the issues, we let the students play an important role by choosing the readings and projects we engage in. In some versions of the course we have a different student choose a popular news article each week that can help facilitate a conversation about an important and timely topic. In other versions of the course we have students develop group projects in which they are given a great deal of latitude to choose their own focus and goals.

Thus far these courses have been quite successful. Each of them has been at or nearly at full enrollment and the course evaluations have been among the best we've ever seen. We are looking forward to more detailed evaluation to further explain the benefits and limitations of such an approach.

*Model II – Embedded in Required Course*

Embedding ethics education in a required core course presents ethics concepts and technical concepts in comparable ways. ASU's new doctoral degree in Biological Design provides an unusual opportunity to embed ethics education. In the first year, students in Biological Design take a single core course, "Fundamentals of Biological Design." This course meets daily for three hours in the fall semester and three times a week for three hours in the spring. It provides the fundamental technical training for the degree program in a modular format and includes material from biophysics, biochemistry, molecular biology, cell biology, developmental biology, immunology, systems biology, biomedical engineering, environmental engineering and synthetic biology.

The research team elected to test two approaches to embedding ethics education into this course. An assistant research professor in science policy, with a Ph.D. in Chemistry, serves as one of two course instructors who attend all class sessions in the fall semester. The science policy professor actively participates in the course and uses the technical curriculum as the starting point to guide students in reflection on macroethical issues. For example, when a visiting scientist discusses the latest research in germ-line therapy or the use of animal testing, the professor seizes the opportunity to expand beyond the technical details to discuss the broader public discourse about the topics as well as the students' own values and concerns. Another project team member leads the microethical component of the course, focusing on the responsible conduct of research using the National Institutes of Health curriculum. The microethics content is delivered in five sessions over the course of the semester.

*Model III – Online Modules*

The third model features online modules linked to existing web-based microethics material and new macroethics material developed under this project. Modules are planned in the following areas:

- Nanotechnology: development of nanomaterials and their use in particular applications
- Real Time Macroethical Assessment: real time responses to macroethical problems in such areas as information and communication technology and transhumanism

- Engineering and Sustainable Development: Efforts by professional engineering societies, engineering schools, and corporations to address the economic, environmental, and social challenges of sustainability
- Engineering Ethics & Computer Ethics: methods and concepts from Computer Ethics with significant implications for engineering research and practice such as intellectual property, privacy, and safety-critical systems

Plans call for the online modules to be piloted in a graduate engineering course in earth systems management as well as a graduate course in ethics and emerging technologies.

*Model IV – Ethics and the Lab*

This model is based on the idea that scientists and engineers sometimes disregard traditional ethics training in the classroom because they don't see how the lessons could pertain to their daily work or how the ethics instructor could understand their situation. Holding these sessions in laboratories where the students are comfortable is a physical way for the ethics instructor to acknowledge that science and engineering ethics can be a cooperative endeavor. The focus of this pedagogy is not to teach the graduate students something completely new, but rather to help them to think about what they already know, analyze it with new tools and perspectives, and reflect on the impact of their daily decisions. This idea of being reflective – the ability to explore where scientific and social values come from, what they mean, and how they may be related to decisions about science and engineering – is a key component of the process to get scientists to engage with ethical and social issues as they conduct their technical practice.

We were able to do a small pilot test of this approach two years ago and had reasonable success with it[14]. It is very different from the other models because it takes as its starting point a group rather than an individual. The goal is not simply to better prepare single scientists or engineers, but to help the group as a whole discuss the ethical decisions they must make together in the lab…decisions that may affect not only their own health and safety but the broader public as well. We hope that by working with existing groups we will be shaping not just individual thoughts, but collective actions.

## Project Assessment

Efficacy of the ethics instruction models will be assessed in four ways: (1) a global quantitative measure of moral reasoning, (2) a quantitative measure of sensitivity to ethical issues in science and engineering, (3) quantitative items of desired outcomes developed specifically for this project, and (4) open-ended questions regarding student perceptions of effectiveness. Research has demonstrated that a primary focus for educators of professional ethics is "students' abilities to recognize and respond appropriately to ethical problems characteristic of their professional practice"[15 p. 377]. Scientists and engineers increasingly encounter ethical dilemmas and issues for which there are no precedents or rules. Accordingly, two instruments will be used to tap the ability to recognize existing ethical issues in science and engineering as well as the ability to reason through ethical dilemmas when decision making standards are not clear. The Moral Judgment Test (MJT)[16] will be used to measure overall moral reasoning. The MJT has been used to assess efficacy of ethics instruction and moral education programs across disciplines and in a variety of cultures over the past 30 years[17]. A shortened version of the Engineering and Science Issues Test (ESIT)[18] will be used to measure sensitivity to domain-specific ethical issues. It is important for graduate students in science and engineering to demonstrate general knowledge of ethical issues they are likely to face as they put their advanced degrees to use. Accordingly, the ESIT will be used to assess gains in ethical reasoning regarding domain-specific issues. Because the ESIT was designed primarily to assess undergraduate ethics education, two sections that are not relevant to the graduate student population will be eliminated for this study. Study-specific assessment items will complement these measures to provide an assessment of efficacy of project instructional models in terms of desired outcomes identified by the project team. Two open-ended questions will provide qualitative data that will supplement quantitative information. One question will ask students to discuss their perceptions of the relevance and value of information presented on social and professional responsibility. Another open-ended question will allow student participants to identify and describe a topic, module, or discussion they perceive to be most memorable and provide reasons.

Each instructional model will include different types of instructor-student interactions, different opportunities for students to engage in discussions about ethical issues, and different instructors. Therefore, it is important to assess potential effects of instructor-student interactions and instructor communication behavior on student outcomes. Previous research has demonstrated clearly that instructor communication behaviors influence classroom learning environments and student learning (e.g.,[19,20]). Accordingly, this project includes measurements of communication behavior and analysis of whether these behaviors are related to outcomes of ethics education. Argumentativeness will be measured using a revised version of the Argumentativeness Scale[20,21]. Verbal aggressiveness will be measured using a revised version of the Verbal Aggressiveness Scale[20,22]. Out-of-class communication will be measured using the Out of Class Interaction Scale[23]. Classroom climate will be measured using the Communication Climate Questionnaire[24]. An additional open-ended question will ask students to describe and evaluate the process by which issues regarding social and professional responsibility were presented/discussed.

Each group of students will be given a pretest consisting of the MJT, ESIT, study-specific items, and demographic questions the first week of instruction. Each group will be given a posttest of the MJT, ESIT, and study-specific items in the thirteenth week of instruction. This assessment design will allow for analysis to compare student gains within and across pedagogical models using standard statistical procedures for assessing group differences. Additionally, students will be given a survey including the communication behavior scales and open-ended questions the fourteenth week of instruction. The quantitative communication data will be used to assess any correlational relationships between instructor-student interaction variables and efficacy outcomes. The qualitative data will be used to conduct thematic analysis of topics and instructional processes participants find particularly useful.

## Coordination Workshop

Ultimately the goal of this project is to develop models, curricula, and assessment techniques that can be used by educators far beyond the walls of our home institution. To that end we will be hosting two workshops that bring together educators to work with us on these issues. The Coordination Workshop (held in February 2009) focused on educational outcomes and instructional methods for integrated approaches to teaching micro- and macroethics to graduate engineering and science students. The Coordination Workshop was held over a three-day period and involved about 20 participants, including the project PI, co-PIs, senior personnel, consultants, advisory board, and additional participants from ASU and other institutions including some who answered an open call for participation. There were six main components to the workshop: (1) workshop consultants presented background of the EESE program and graduate education issues in science and engineering; (2) ASU project personnel described each of the four instructional models; (3) participants divided into discussion groups to develop ideas about microethical and macroethical issues and desirable outcomes regarding those issues for graduate education in science and engineering, followed by general discussion of group reports; (4) participants divided into discussion groups to develop ideas about instructional methods for the four curriculum models, followed by general discussion of group reports; (5) planned assessment strategies for the project were presented, followed by a general discussion of assessment challenges and additional methods to incorporate into the assessment plan; and (6) a general discussion to summarize desired outcomes of micro/macro issues to include in models and assessment of the project.

Because workshop participants represented diverse perspectives and backgrounds, the discussion throughout the workshop was lively, but we did find a fair amount of common ground. We ultimately agreed that there is not a firm line between microethics and macroethics. In general it seemed right that microethics involves decisions made by individuals and macroethics is the domain of larger groups of people and institutions. Yet at the same time we acknowledged that individuals must ultimately work within and make decisions about both realms. We teased out a number of topics that students should be exposed to in each category. Examples of microethics topics include: (1) the importance of identifying students' own interests and values; (2) an appreciation of professional norms such as objectivity, transparency, accuracy, and efficiency; (3) realistic understanding of behaviors; and (4) challenges of the reward structure of their jobs. Examples of macroethics topics students should be exposed to include: (1) the place and importance of sociotechnical systems in our daily lives; (2) the various overlapping contexts of research (i.e., institution, profession, economy, society); (3) ways to envision the possible social implications of research; (4) ability to identify values and stakeholder interests; and (5) examples of how different career paths lead to different macro-ethical implications and outcomes (e.g., pacifists in military jobs).

The consultants, advisors, and visitors agreed that the ambitious goal of this project to integrate microethics and macroethics was well worth pursuing. We worked to formulate ways to integrate the two spheres. There was much discussion about how to conceive of the relationship between micro and macro issues. Are they overlapping contexts, such as a Venn diagram might convey? Are they different levels of abstraction and application to consider? Are they in an inherent duality of action and structure, such as described in structuration theory? As a group we agreed that instruction in both micro- and macroethics was incredibly important for students pursuing science and engineering degrees. And although there might be some value to artificially separating the two categories early on in instruction, ultimately people will have to deal with both simultaneously and thus we developed a short list of topics and approaches that could help students envision and address them together. Examples of these strategies include:
(1) recognize that the day-to-day work of scientists and engineers requires extensive social and

institutional decision-making; (2) recognize that small personal decisions can have an effect on group dynamics and institutional decisions; (3) develop habits of mind; (4) educators need to create a space and opportunity to discuss these kinds of issues; (5) demonstrate the importance of moral imagination; and (6) encourage students to recognize their own biases and weaknesses. There was general agreement that helping graduate students understand the various contexts they will be required to work in and make decisions about is key to producing more ethical engineers and scientists.

One of the most exciting benefits of the workshop for the PI and Co-PIs was the detailed feedback we received on the instructional models we have been developing. We received valuable feedback regarding strategies that have already been piloted and ideas for refining each model. We will incorporate this feedback in refining our course designs.

The final session of the workshop was a review of our assessment procedures. This was easily the most contentious part of the weekend. This contention rose in part because some participants were generally suspicious of assessment tools (especially quantitative ones). But perhaps more importantly, participants questioned whether the planned assessment tools would tap all possible student learning regarding micro- and macroethics. One idea that recurred during the workshop was the importance of teaching students about the broader social sphere and the contexts in which they do their work. There was general concern about spending considerable time testing students to see if they learned ideas and ways of thinking that are removed from such lessons. There was general agreement that assessment should include multiple methods. It was also suggested that assessment should include ways to evaluate interaction processes that occurred in each model, which would assist in making models transferrable to other institutions. To further complicate this, it was generally agreed that there needs to be separation between the instructors and the evaluators so that the data collection is not compromised. At the same time, there will need to be some collaboration to ensure that in general the students are evaluated on what is being taught. Thankfully the consultants agreed to continue to advise the project on this and other issues. Finally, there was some concern about evaluating the different models against each other. The overall stated goal of the project was to see which models were effective for which learning goals. The idea is that probably some of the approaches are better at some things and other approaches are better at other things. The participants wanted to make sure that the evaluation procedures did not simply give a green light to some models and argue against the use of other models when they all might have their own strengths and weaknesses.

Overall the workshop was a great success. As the first step in a three year project we came a long way in a very short time. We appreciated the ideas generated and collaboration fostered by workshop participants. It was agreed that the workshop was an important part of developing a quality project.

**Results Dissemination Workshop**

At the end of the three-year project a Results Dissemination Workshop will be held to reconvene the Coordination Workshop participants to discuss project results in comparison with the goals and outcomes identified in the Coordination Workshop. Several graduate students who have completed the instructional models will attend the Results Dissemination Workshop and share their experiences with the participants. In addition eight to ten participants from other institutions (partially funded by the NSF grant) will learn about the project results and "Best Practices" for integrating micro- and macroethics education in graduate science and engineering.

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