Sci Eng Ethics (2013) 19:599–623
DOI 10.1007/s11948-011-9332-9

Introducing Survival Ethics into Engineering Education and Practice

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Received: 22 June 2011 / Accepted: 24 November 2011 / Published online: 9 December 2011

Abstract Given the possibilities of synthetic biology, weapons of mass destruction and global climate change, humans may achieve the capacity globally to alter life. This crisis calls for an ethics that furnishes effective motives to take global action necessary for survival. We propose a research program for understanding why ethical principles change across time and culture. We also propose provisional motives and methods for reaching global consensus on engineering field ethics. Current interdisciplinary research in ethics, psychology, neuroscience and evolutionary theory grounds these proposals. Experimental ethics, the application of scientific principles to ethical studies, provides a model for developing policies to advance solutions. A growing literature proposes evolutionary explanations for moral development. Connecting these approaches necessitates an experimental or scientific ethics that deliberately examines theories of morality for reliability. To illustrate how such an approach works, we cover three areas. The first section analyzes cross-cultural ethical systems in light of evolutionary theory. While such

Portions of paper adapted from Verharen and Tharakan (2010), Verharen (2006), (2008b).

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research is in its early stages, its assumptions entail consequences for engineering education. The second section discusses Howard University and University of Puerto Rico/Mayagüez (UPRM) courses that bring ethicists together with scientists and engineers to unite ethical theory and practice. We include a syllabus for engineering and STEM (Science, Technology, Engineering and Mathematics) ethics courses and a checklist model for translating educational theory and practice into community action. The model is based on aviation, medicine and engineering practice. The third and concluding section illustrates Howard University and UPRM efforts to translate engineering educational theory into community action. Multidisciplinary teams of engineering students and instructors take their expertise from the classroom to global communities to examine further the ethicality of prospective technologies and the decision-making processes that lead to them.

Keywords Philosophy of engineering · Survival ethics · Checklist model · Cross-cultural ethics · Multidisciplinary education · Appropriate technology

Introduction

Recognizing the impact of mankind on Earth's processes, many scientists now refer to the present Earth Age as the *Anthropocene* (*The Economist*, 28 May 2011). For the first time in our ~200,000 year history we are developing capacities to transform life through synthetic biology and global atmospheric change (Kintisch 2009, 2010; Gardiner 2011; Kaiser 2010; Cerutti 2010). Dual use technology applications of nuclear and biological sciences threaten human life in particular (Pustovit and Williams 2010). These crises call for a consensual ethics that furnishes effective motives to take global action necessary for survival.

We propose a research program for understanding why ethical principles change across time and culture. To this end, we will examine two kinds of revolutions in ethics. The first concerns the dramatic changes in ethical principles expressed across African, Asian and European cultures. The second examines our expanding sense of ethical community culminating in the United Nations declarations of human rights.

Our examination of revolutions in ethics leads us to propose an ethical system, a "survival ethics," derived from the evolutionary consideration that survival is the precondition for the exercise of all ethical virtues. Ethicists who have proposed the hypothesis that moral judgments convey no truth or falsity dismiss this reflection (Greene 2003; Blackburn 1993; Mackie 1977). However, moral judgments have empirical consequences. In recent experimental efforts to link ethics and science, philosophers and psychologists trace such judgments to emotive or reasoning processes through fMRI (functional Magnetic Resonance Imaging) techniques (Greene et al. 2001). A growing literature proposes evolutionary explanations for moral development (Vogel 2004; Joyce 2006).

Connecting these approaches necessitates an experimental or scientific ethics that deliberately examines theories of morality for reliability. To illustrate how such an approach works, we cover three areas. Paying attention to African and Asian as well as European cultures, the first section analyzes ethical systems in light of evolutionary theory. While such research is in its early stages (Miller 2008), its assumptions entail consequences for engineering education.

The second section presents Howard University and University of Puerto Rico/ Mayagüez courses that bring ethicists together with scientists and engineers to unite ethical theory and practice (Davis 2003). We include a syllabus for engineering and STEM ethics courses and a checklist model for translating educational theory into community action. The model is based on aviation, medicine, and engineering practice.

The third and concluding section illustrates Howard University and University of Puerto Rico/Mayagüez efforts to translate educational theory and practice into community action. Using the checklist model, multidisciplinary teams of engineering students and instructors take their expertise from the classroom to global communities to examine further the ethicality of prospective technologies and the decision-making processes that lead to them.

Part I. Survival Ethics Theory: To be Good is First to be

Ethical systems specify life's basic values and appropriate means to achieve them. Haidt (2007) claimed that although ethical systems vary culturally, they all include a set of basic values: fairness, loyalty, respect for authority and spiritual purity. While agreeing on the importance of these values, we suggest an alternative approach that recognizes a more fundamental set of values justified by their direct survival utility. Renowned thinkers have singled out these values, and cultures through the ages have exhibited dependence on them. Principles like Haidt's fairness and loyalty may be derived from this foundational set.

There are two basic values in this *survival ethics system*. The first is survival itself: *To be good is first to be*—both for individuals and the communities to which they belong. All other values follow from this first principle because no other values exist in the absence of life itself. The second value is flourishing, inasmuch as survival is better achieved when life flourishes. Values such as rationality, community bonding, pleasure, freedom, and introspection or meditation define flourishing.

The fact that survival is the pre-condition for all other values does not mean that survival of self is the most important value. Revered figures like Socrates, Christ, Gandhi and King sacrificed their lives for the sake of duty, love and freedom—and the survival of other members of their communities (Ridley 1998; Axelrod 2006). However, analyzing values in the light of survival can help bridge the differences between competing ethical systems. And focusing on the preconditions for survival presents a model for objectivity in ethics.

Human survival is itself dependent upon five unassailable goods: clean air, temperature control through clothing and shelter, potable water, nutritious food, basic healthcare and education in descending order of immediacy. The ranking order is operative for all human societies. That objective fact cannot change, regardless of cultural orientations.

Beyond the bare facts of survival, however, is the contentious nature of ethics. Philosophers like Hume trace the failure to achieve objective consensus in ethics to the distinction between facts and values. The conditions for survival are matters for scientific discovery. Whether other values should take precedence over survival, and whether all humans have a right to survival are matters for ethical decision.

However, just as Newton demolished the distinction between celestial and terrestrial motion with laws of universal gravitation, ethical theorists like Joyce (2001) and Harris (2010) attempt to collapse the distinction between the "is" and the "ought." Values like survival, freedom, love spring from desires. Desires are facts. How desires arise and whether desires are appropriate for achieving desired ends are matters for scientific investigation (Lekka-Kowalik 2010). Joyce (2006) collapses ethics into the neurobiological and psychological sciences in an effort to explain the origins and development of ethics by means of evolutionary theory. The mainspring of this kind of explanation is genetic change and natural selection.

More traditional philosophers like Appiah (2008) admit that ethics has always been an experimental discipline. However, Appiah insists that scientific generalizations cannot have the force of ethical prescriptions. The fundamental values that set the course of our lives are matters for choice rather scientific delineation.

In this essay we claim that choices and reasons for choices are themselves subject to empirical investigation. Human choices of basic values have changed dramatically over time. We propose generalized explanations for significant changes in ethical systems. The essay's method is philosophical rather than empirical. It furnishes guidelines for empirical research rather than specific claims. More importantly, it proposes a method for achieving consensus on urgent ethical decisions confronting global engineering communities.

The Structure of Revolutions in Ethics: Defining What is Good

There are at least two kinds of revolutions in ethics: one focused on defining what is good and the other on defining populations covered by ethical systems. Thinkers across Africa and Eurasia outlined the first kind of revolution over two thousand years ago. While those same thinkers sketched proposals for the second kind of revolution at the same time, their proposals are only beginning to be acted on in recent times.

The term *ethics* has acquired the sense of a field distinct from morals. For the purposes of this essay, the term *morals* refers to behavior that is customary or acceptable in a given society. *Ethics* means the study of morals and more deeply the study of value itself (Haws 2004). What is valuable is what is desired or, more strictly, what is desirable given some set of fundamental assumptions.

At its most basic level, ethics considers appropriate mechanisms for choosing principles or values to guide our lives. The history of African and Eurasian ethics presents a medley of sometimes conflicting goods. Early African and Asian primary values appear to be commonsensical and grounded in the conditions necessary for human survival and flourishing. The oldest written philosophy, that of ancient Egypt starting around 2800 BCE, presents *maat* as the highest good. *Maat* is variously translated as harmony, order, peace, justice, tranquility (Hornung 1971/1982).

Other African cultures like the Oromo in Ethiopia emphasize a similar overriding ethical principle. The principal ethical good of the Borana, the Oromo group in the southernmost part of Ethiopia bordering on Kenya, is *nagaa*, translated as peace or harmony. The Oromo ensure a community-wide harmony among themselves, their neighbors, and the environment through a democratic system called *gaada* (Verharen 2008a).

The ancient Chinese philosophy of Taoism, canonized by Lao-Tzu and Chuang-Tzu around 600 BCE, enjoins the ethical principle of *wu-wei*, translated as passive non-doing. The Taoists, as their name suggests, believe that the universe is comprised of a single principle, the *Tao*, which is a balance of complementary principles striving for harmony. As the *Tao* or nature seeks its balance, humans live well if they follow nature's guiding principle of harmony rather than forcefully imposing an artificial system of control on nature (Chan 1963).

The common-sense principles of *maat, naaga*, and *wu-wei* contrast sharply with the ethical maxims of other ancient traditions. Hindu philosophy enjoins a value of *moksha* or liberation from our common-sense conviction that this life we live daily is real rather than a dream (*maya*). The primary ethical practice of this tradition is meditation, known through the practices of yoga, or the union of self (*Atman*) with god (*Brahman*). Buddhism dispenses with the metaphysical presuppositions of Hinduism to focus on a single practical problem—how to eliminate suffering or achieve *nirvana*. Like Hinduism, however, Buddhism focuses on meditation as the instrument of liberation from suffering (Radhakrishnan and Moore 1967).

Plato's concept of the good is the very idea of good itself. For Plato, the whole point of life is to contemplate the perfect model of all that is good. Plato stands out among Greek ethicists for making the contemplation of the good by an immortal soul the overarching end of humanity. Other Greek ethicists are much more down to earth. The hedonists notoriously make pleasure the end of all ends.

Aristotle rejects pleasure and substitutes *eudaimonia* or happiness. He defines happiness as activity in accord with excellence (Harris 2008). Excellence is a function of the nature of an organism. As rational beings, our highest activity is thinking, and the greatest kind of thinking is thinking about thinking itself, defined by Aristotle as contemplation or philosophy.

Augustine carries on the theoretical Christian tradition of universal, unconditional love as the primary ethical principle. However, this principle, first enunciated by the now little known Chinese philosopher Mo Di (also Mozi, Mo Tzu) in the fifth century BCE, is honored more in the breach than in the observance.

Subsequent ethicists in the European tradition subscribe to more common-sense ethical principles: pleasure for Bentham and Mill; duty expressed through universalization for Kant; freedom for Hegel, Marx, and the existentialists; and the return to the basics of survival and flourishing by American pragmatists like James, Dewey, and Rorty.

These apparently quite diverse and seemingly random ethical goods can be reduced to a basket of seven fundamental values. The basic values are survival, flourishing, rationality, community bonding, pleasure, freedom, and introspection or meditation. They cut across African, Asian, and European traditions, and they are associated with the most illustrious philosophers in the traditions of these continents. The common key values are the following: survival for Darwinists, pragmatists, Taoists, and ancient Africans; pleasure for hedonists, Bentham, and Mill; rationality for Plato, Spinoza and Kant; love or caring for Christians, Mohists, and feminists; happiness for Aristotle; freedom for Marx; and introspection or meditation for Hindus, Buddhists, and many Judaic, Christian, and Muslim sects.

Other important values like Haidt's loyalty and obedience to authority, Nietzsche's will to power, or Rawl's justice as fairness may be reduced to survival ethics' seven core values. Loyalty and obedience to authority are aspects of community bonding. Power is justified through its links to survival and freedom. Justice derives from the universal generalizations of rationality (e.g., Kant's categorical imperative) and community bonding buttressed by empathy. Our reduction is provisional and contingent upon further empirical research (Appiah 2008; Haidt 2007; Hauser 2006; Greene et al. 2001; Greene 2003; Joyce 2001; Miller 2008; Harris 2010; Vogel 2004). Its purpose is twofold. First, it serves as a heuristic device for cross-cultural research aiming toward global consensus on values. Second, it serves as a provisional standard for ethical judgments that must be made in advance of consensual research findings.

Can these disparate values be ranked or does each hold an independent status? Survival may under certain circumstances trump all other values—particularly for communities or for the whole earth population when survival is at risk. To be good, we repeat, is first to be. If survival is not an issue, however, it may deserve little consideration in choosing the fundamental values that are to serve as guidelines for one's life.

Nonetheless, the seven selected values may be given an explanation through evolutionary considerations. Rationality is defined here as selecting appropriate means to achieved desired ends. Rationality is based on the human capacity for reasoning, the ability to form generalizations that allow us to predict and thereby control our circumstances. Rationality is a primary instrument of human survival.

Pleasure is a stimulus for behaviors necessary for the survival of the species—breathing, temperature control, hydration, eating, reproduction, and the like (Varner 2008). Love is indispensable for human survival, given the long maturation period of humans and the need for community bonding for group survival. Variation is key to survival, and the value of freedom or creativity promotes variation (Martin 2006). Introspection or meditation may seem to be quite disconnected from the immediate concerns of survival. However, the primary focus of meditation is the control of the attention. Ordinarily, random environmental circumstances dictate the attention's direction. Survival under this condition is a matter of luck. Meditation gives the individual rational control of her attention.

Survival ethics' values have at least three justifications. The first proceeds from Darwin's hypothesis that ethics can be given an evolutionary explanation. Haidt (2007), Hauser (2006), and others' research into the homogeneity of ethics across cultures relies on the heuristic that innate principles genetically conveyed allow us to get along in ways that move us from a mere handful in the "African Eve" group to 7.0 billion strong.

A second justification is the fact that the primary ethical values listed above have served as "mission statements" for billions of humans over five thousand years of recorded history. A third justification for a globally shared set of values is the consensus on human rights expressed in United Nations declarations (1948 et al.).

The fact that basic human values may be grounded in considerations of survival does not confer a privileged status on survival. In fact, we may deliberately choose to dismiss survival as a ground value. We may very well be the kind of species that sets up the "ethical" conditions for our own extinction. Powerful historical slogans point in this direction: "Live free or die!" "Give me liberty or give me death!" "*Patria o muerte*!" Religions like Hinduism, Buddhism, Judaism, Christianity, and Islam proclaim that this life is merely a test. "Real" life starts only after death or transcendence of life.

However, the fact that the survival of the species may be at risk in the future makes survival an issue of overriding contemporary concern. The key question is whether enough humans believe that a primary mission of our lives is to pass life on to our successors in better condition than we have received this gift. If this proves to be the case, we need a new "technology" to furnish the grounds for continuing life. This technology must synthesize four disciplines: ethics or philosophy, science, engineering and technology itself. The technology must find a common ground for a "whole earth" ethics that the majority of humans, regardless of their individual cultures and religious beliefs, can subscribe to. This new ethics must have as its primary focus the survival of the species.

Can a "survival ethics" help to reduce the wrangling that notoriously characterizes the history of ethics? Survival ethics recognizes the merits of virtually all classical ethical systems (Bouville 2008). As Aldous Huxley points out, the brain is a "reducing valve" that attempts to categorize all phenomena under single concepts. Classical ethicists' quests to reduce all values to a single ground value mirror the efforts of contemporary physicists to reduce the laws describing gravitational, electromagnetic, and nuclear weak and strong forces to a grand unifying theory or theory of everything.

Survival ethics insists that reduction of ethics to a single value is a gross oversimplification. Survival is not a value that trumps all other values. It is merely the precondition for the exercise of other values. These values may in fact have sprung from genetic mutations and natural selection in an evolutionary process, but that is merely a heuristic or speculative principle guiding further research. In the best of all possible ethical worlds, survival would be so well assured that it would not merit reflection. By way of analogy, consider how we do not think about taking our next breath—except in the most pressing circumstances or in a meditation exercise. We should strive to reduce the role that survival plays in ethical reflection, but our circumstances do not permit that liberty now.

In the interest of achieving global consensus in ethics, survival ethics makes no claims about supernatural, spiritual, or genetic justifications of ethical principles. Kant proposed a "categorical imperative" that could serve as the ground for all ethical obligations. Survival ethics proposes only hypothetical imperatives: If you wish to survive, then you should strive to flourish. If you wish to flourish, you must choose the appropriate balance among five values: rationality, community bonding, pleasure, freedom, and introspection. That balance cannot be specified in advance, as it depends on environmental and cultural circumstances. Variation in choices among those five goods contributes to the variety that is not simply the spice of life but the stuff of life.

The Structure of Revolutions in Ethics: Expanding Our Sense of Ethical Community

Are we becoming more ethical over time? Wrangham (2004; Pinker 2011) makes the startling claim that intraspecies kill rates among humans have declined over the past 10,000 years—in spite of the genocide and global wars of the last century. Humans in hunting/gathering or proto-agricultural groups exhibited intraspecies kill rates comparable to those of wolves and chimpanzees. The three species occupy a territory, patrol its perimeter, and invade neighboring territories. What has changed for humans over time are the bonding principles and sizes of our groups. Those two factors drive revolutions in ethics. Other things being equal, the larger the group and the stronger its bonding principles, the better the group's chances of survival and flourishing. Empathy is key to group bonding. Empathy's targets expand as expanding groups increase their control over their environmental circumstances.

Early humans lived in small, genetically and linguistically bonded groups. Diamond (1999) claims that the first ethical revolution with respect to community definition was the realization that it was not always necessary to kill strangers. The second revolution was the theoretical conviction expressed in the period before the contemporary era that all humans constitute a single group with identical ethical rights and obligations. The third revolution was the conviction expressed by Locke (1991), first African American Rhodes scholar and PhD in philosophy from Harvard, that the greatest bonding principle of human communities should be the fact of our cultural differences. Variation is indispensable to survival.

The evolution of an expanded sense of ethical communities displays itself in four distinct stages. The first stage is *egocentrism*. This stage precipitates the social contract theories developed by Hobbes, Rousseau and Locke. Infants and infantile cultures recognize moral obligations to others only insofar as those others are useful to them.

The second stage is *ethnocentrism*. Here individuals merge seamlessly with their groups. Ethnocentrism is the condition of the bulk of humanity from its origins to the present as a result of isolated groups' inability to control their circumstances.

The third stage is *anthropocentrism*. Revolutionary thinkers like Mo Di, Crates (a Greek Stoic philosopher), Christ and Nagarjuna (a Hindu philosopher) claimed that all humans constitute a single group. Their idea subverts the hypothesis that groups necessarily compete against one another and that only the fittest survive. Their implicit wisdom is to recognize that survival is a function of group size and bonding power. Christ made the extraordinary claim that the bonding power of the entire group of humans should be universal and unconditional love. The extreme manifestation of that love is giving up one's own life for the sake of one's enemy—Christ dying for the sake of those who have acted against him (Eisenbarth and Van Treuren 2004).

Some two thousand years after these revolutionary philosophers proposed their "unnatural" ethics, the world has recognized that all humans do indeed constitute a single group. However, the universal ethics codes enunciated in United Nations declarations of universal human, indigenous peoples, and children's rights are not always honored. The very existence of these codes is contingent upon the UN member nations' confidence in their ability to control their circumstances.

The fourth stage of ethical revolutions, *acentrism,* is still on the horizon. It is the product of empathy's expanding range. This stage recognizes the moral standing of non-human entities. Its precursors are biocentrism, the ethical ideal that life forms have moral standing, and ecocentrism, the idea that even the inorganic features of the planet have moral standing. United Nations delegations from the Global South are now lobbying for biocentric and ecocentric provisions to supplement the universal declarations of human rights. Acentrism's advent as an ethical revolution is made possible by the fact that humans are beginning to exercise control over the whole-earth environment. Such control enables an increase of our capacity for empathy. This revolutionary potential calls for an ethics aimed at the species' survival.

We must be ethical to survive—whether our ethics are those of egocentrism, ethnocentrism, anthropocentrism or acentrism. As egocentrists, we must respect all the organisms constituting the macro-organism we call our bodies, ourselves. As ethnocentrists, we must respect the other selves that form the tightly bonded communities that make our survival possible. As anthropocentrists with Mo Di and Christ, we realize the importance of forming the largest, most tightly bonded group to multiply our chances of survival. As acentrists, we realize that we are not isolated organisms, but simply constituent parts of an organic whole we call earth or *Gaia.*

Our progression from egocentrism through ethnocentrism and anthropocentrism to acentrism is made possible by our increasing power to control our circumstances, our environment. (De-centering is a hallmark of rationality. Progression from centrism to acentrism in ethics is analogous to the movement from geocentrism to heliocentrism, galactocentrism and acentrism in physics.) As we approach unprecedented control over our environment, we begin to uncouple ourselves from the natural philosophical constraints imposed on us by evolution.

Four great fears have helped drive our philosophical speculations. Millions of years of evolution have implanted in us the drive to survive, the fear of death. From earliest to our own times, the most popular religions dispel that fear with the claim that this life is only a test. Our *real* lives begin only after death.

Our vulnerability to death is a function of our ignorance. The greatest peril to our survival is ignorance. In the face of intractable ignorance, we displace our fear of ignorance through philosophical or religious systems that give us the wisdom to know god(s) as our point of origin and our souls as our guarantee of immortality.

Our third fear is loss of control. Unlike our fellow animals, we survive by our wits rather than through instinct and natural weapons like claws and jaws, muscles and speed, keen senses. To lose control is to risk death. Where we cannot control our circumstances through our own rational efforts, we hope that we can petition god(s) through acts of prayer, sacrifice, and other behavior. When there is no apparent response to our prayers, we assume that the will of god is always for the best.

Our fourth fear is loss of community. We cannot survive without our community bonds. Historically our religions have been the greatest bonding powers of our groups. Until quite recently, even nationalism has been grounded in religion.

These four basic human fears help generate philosophical or religious beliefs in immortality, a supernatural creator, the power of prayer, and communities bonded by religious conviction. As human groups acquire greater control of their circumstances, the perceived necessity of such beliefs may diminish. Such control acts as a counterforce to the four fears.

Increasing control of the whole-earth environment sets the stage for atheistic ethics envisioned by Marx and expressed in varying degrees in the Soviet Union, China, Vietnam and Cuba. In atheistic ethics, being ethical requires no motive beyond itself, whereas in theistic ethics, immortality and morality are intertwined. Communists are ethically obliged to sacrifice their lives for the sake of the universal freedom conferred by universal revolution. For them, death is final. Christians are obliged to sacrifice their lives for the sake of universal love. However, that self-sacrifice is rewarded with the eternal bliss of being face to face with god for eternity.

As humans through their technologies begin to develop a sense of control over destiny, the need to conjoin morality and immortality may diminish. Whether such diminution is provident is beyond the scope of survival ethics. Survival ethics remains silent in the face of metaphysical speculation. Nonetheless, the human sense of control may accelerate should we acquire greater power to alter life on earth. Synthetic biology may supplant natural selection with intensified artificial or human selection. We developed our household pets, our domesticated grains and animals over a period of thousands of years. Our capacity for genetic engineering presents ethical dilemmas that must be solved in a much briefer span of time.

For the foreseeable future, ethics must take survival as its precondition. A fusion of science and ethics will work out the rules for deploying supporting values and their enabling actions. As the Senegalese historian Diop said, “ecology, defending the environment,” must become a “foundation” for a new ethics “because of the one fact that the future of humanity is at stake.” Ethical commands issue from what the “science of the epoch” discovers to be “harmful to the whole group” (Diop 1991, 375).

Philosophers assign hierarchies to the abstract values of traditional ethics depending on local and global circumstances. Scientists must translate abstractions into descriptive generalizations or laws. A philosopher might propose a course of action to achieve an ethical end. A scientist will have to judge the theoretical merits of the action. An engineer must judge the practical merits of the action. No single individual is competent to judge whether proposed means will produce desired ends. Only a multidisciplinary approach can judge the ethicality of proposed technologies.

Part II. Survival Ethics in the Engineering Classroom

What are the practical consequences of survival ethics for educating engineers—or even the public? How can one know whether a proposed technology development in one’s community is ethical? Can the public make informed, rational judgments without education in ethics, science and engineering? Elementary and secondary education curricula would have to include more attention to the ethical consequences of proposed new technologies. This would necessitate teaching theoretical scientific material with an eye to practical application (Kabo and Baillie 2009).

While the consequences of survival ethics for education range far beyond this essay's scope, we note the successful application of its principles to the engineering education programs developed over the past few years at Howard University and the University of Puerto Rico/Mayagüez (UPRM). Initial efforts focused on infusing ethics into the curriculum have shifted toward expansion into real-world community applications.

Faculty at UPRM have established partnerships with organizations to assist in identifying communities and appropriate technology projects: the Centro Universitario para el Access/University Center for Increased Access (CUA), which organizes outreach activities from UPRM to local schools that serve economically disadvantaged students; the Instituto Universitario para el Desarrollo de las Comunidades/University Institute for Community Development (IUDC), which organizes service learning projects; and YouthHaiti, which assists sustainable development in Haiti.

At Howard University, faculty from the philosophy, biology, anthropology, systems and computer science, chemical, civil, and electrical engineering departments inaugurated a course on ethics and appropriate technology (Graber and Pionke 2006). Offered as a successful pilot project over several semesters, the course focuses on small-scale technologies, but may be scaled up for larger applications (Tharakan et al. 2006).

A motive for starting the course was faculty consensus that no single academic discipline is competent to judge the ethicality of proposed technologies. In addition, College of Engineering, Architecture and Computer Science international students, most from developing countries, urged faculty to inaugurate courses and processes that would enable students to contribute meaningfully to development upon their return home (Harris 2004). Faculty members agree that the ethical values of such courses must be globally acceptable.

Responding to the course with enthusiasm, faculty and students recommended including the course in the engineering curriculum. With minor modifications, the course is offered in Spring 2012 at Howard and a comparable course is offered at UPRM in the same semester (see Graduate Education for Research and Appropriate Technology 2010). The Howard course is titled Philosophy and Ethics of Appropriate Technology. Its interdisciplinary nature includes the following topics: The Social Effects of Technology, Appropriate Technology, Philosophy of Technology, Philosophy of Engineering, Engineering Ethics, and Community Service. Key themes in the course will include Good-Work Projects, Responsibility, Social Justice, Competition, Cooperation, Education, and Revolutions in Ethics (Son 2008).

The course's interdisciplinary subject matter makes it desirable to have a class of students with diverse backgrounds and different areas of study. The interaction between students reacting to the course material is one of the most valuable outcomes of the course.

The purpose of this course is to integrate survival ethics theory with engineering practice (Fleischmann 2004). It exposes students of different disciplines to the technology development process and its role in shaping global societies. Special attention is given to ways in which individuals from diverse disciplines can contribute to a positive change in technology (Zandvoort et al. 2008).

The goals of the course include:

Goal 1: To engage students in interdisciplinary ways of thinking critically about integrating survival ethics and engineering research.

Goal 2: To empower students through information literacy to become self-directed practical ethicists through a life-long learning process.

Goal 3: To educate students to conduct, write about, and present research incorporating survival ethics and engineering practice.

The course combines lecture and seminar formats. Invited speakers from appropriate disciplines provide lectures on background information prior to discussion sections and seminar engagements. The pedagogical approach is problem-based and case-specific. Case studies focus on ethical issues related to a particular appropriate technology development project. In their major projects, students choose an appropriate technology area of focus and a developing country site with particular needs that might be addressed by appropriate technology.

Student research presents a comprehensive review of the chosen appropriate technology area from theoretical and applied perspectives along with articulation of the particular development problem being addressed, with attention to political, economic, cultural, ethical and technological issues. Students develop solutions to their chosen problems and defend their choices through ethical assessment of the development and implementation process.

The syllabus for the course is adapted from a generalized syllabus format that may be used for courses in ethics and the STEM (Science, Technology, Engineering, and Mathematics) disciplines.

A Syllabus Outline for an Ethics and STEM Course

Week 1: Rationale for survival ethics in the STEM curriculum, examples of science, technology, engineering gone wrong. Relation of ethics to conduct codes and legal codes for professional organizations (Stieb 2011; Bullock and Panicker 2003).

Week 2: History of ethics, correlation of ethics, societal structure and environmental conditions in selected areas of Africa and Eurasia. Staub (1989) on the origins of genocide and warfare.

Week 3: Locke (1991) on universal ethics derived from conflation of philosophy, psychology and anthropology. Haidt (2007), Hauser (2006) on current conflation of psychology and philosophy in "experimental ethics" (fMRI and cross-cultural experimentation with "trolley dilemmas"). Additional input from biological sciences and evolutionary theory regarding the usefulness of ethical frameworks for societies.

Week 4: Structure of ethical revolutions—5,000 year timeline, culminating in UN Declarations of Universal Human, Children and Indigenous Peoples' Rights. Prospects for UN Declarations of Animal Rights, and Nature's Rights. Inclusion vs. exclusion of groups, populations, empathy and rationality as driving principles.

Week 5: Survival ethics as heuristic for triage of basic ethical goods. Emergency room and checklist analogies. Basic goods (air, temperature control, water, nutrition, healthcare, education) vs. thriving goods maximizing access to survival (rationality, introspection, community bonding, pleasure, freedom).

Week 6: Translation of theoretical ethics to STEM practice. Definitions of "appropriate" technology, examples of macro and micro appropriate technology.

Week 7: Case Studies Selection Principles: For maximum impact, the cases must be such that no matter what outcome is chosen, harm will be done (Keefer 2005; Monk 1997; Lozano et al. 2006). The point of an ethical decision to minimize damage. Role of Rawls' Veil in decision-making process (Rawls 1971). Assessing and valuation of impacts on stakeholder groups. Role of participation (see Environmental Justice; Executive Order 12898). Historical examples: Manhattan Project, biological and chemical warfare, dual use technologies, virus eradication (smallpox, polio).

Week 8: Case Studies for basic ethical goods: Air. Temperature Control. Water. Nutrition. Healthcare. Education.

Week 9: Case Studies for ethical goods aimed at flourishing: Rationality. Introspection. Community bonding. Pleasure. Freedom. STEM university-level education and its preconditions in high schools and elementary schools. Re-engineering work conditions that do not require conscious human input. Cell phones replacing landlines and computers as appropriate technology. Re-engineering resource use for sustainable and equitable global distribution of goods and services.

Week 10: Illustrate the dependence of STEM on other professions (economics, government, all social and physical sciences, humanities (including history), all fine and practical arts to accomplish week 9 objectives. Stress the need to make expert knowledge available but more importantly desirable to wider populations. Survival ethics and service learning (Passino 2009).

Week 11: Ensure students' continuing access to journals and other literature to keep up with developments in experimental ethics and its evolving relationships to other disciplines and professions. Introduce students to the checklist method (see below) of judging the ethicality and appropriateness of proposed technologies.

Week 12: Preview of applications of ethics to capstone senior year design projects, and sophomore and junior year design projects leading to and making possible the capstone projects (Catalano 2004; Davis 2006).

Week 13: Concentration on projected course outcomes; service learning courses enabling engineering and other students to distribute their expertise into wider communities. Ethical evaluation of hypothetical or proposed technology interventions across a wide array of cultures through checklist methodology (see next section).

Week 14: Project Design Evaluation Presentation.

An Ethics Checklist for Classroom and Field Application

A checklist method can serve as bridge between classroom and field work in engineering. The checklist model derives historically from professional practice in aviation (Turner 2001) and more recently from hospital (Provonost and Vohr 2010; Gawande 2009) and engineering (Graedel and Allenby 1995) practice. Checklist items serve as reminders of steps to be taken while engaged in life-critical measures.

The items on the checklist are taken directly from the seven principles of survival ethics developed in the essay's first section.

Two points are key in using checklists. First, careful use of a checklist does not always guarantee successful outcomes. Checklist items must be applied in the context of collective professional practice. Second, correct use of the checklist items is a matter for professional judgment rather than algorithmic rule application.

In the context of survival ethics, not only scientists and engineers but also social scientists, ethicists and members of the communities in which technologies are to be deployed may use the checklist for collective decisions. Where practical, social science professionals should include economists, political scientists, psychologists, anthropologists, sociologists, and social workers (Veslind 2001). Physical science specializations will vary according to the nature and environmental context of potential projects, but at the very least biologists, chemists, physicists, and environmental (including earth and atmosphere) scientists should be on call. Participation of ethicists with field experience is critical.

Survival ethics theory as elaborated in the paper's first section justifies the inclusion of the checklist items. Detailed attention is given to a separate checklist for rationality for two reasons. First, rationality is the ground for assessment of any project, whether in technology, engineering or science. Second, the constituent features of rationality have been explicitly detailed in the history of philosophy and science.

Item 1: Survival

Does the proposed technology promote the survival of those for whom it is intended? Survival is contingent on access to five basic goods: clean air, temperature control through appropriate clothing and shelter; potable water; nutritious food; minimum healthcare; basic education.

Item 2: Flourishing or Happiness

Does the proposed technology promote the flourishing of those for whom it is intended? The concept of "flourishing" takes its meaning from biology. We speak of organisms as flourishing if their basic needs beyond mere survival are met. Definitions of flourishing are context dependent. However, at a minimum flourishing must include access to rationality, pleasure, community bonding, freedom or creativity, and introspection or meditation. Other goods such as truth, justice, duty, spirituality, may be derived from this core set of values.

Item 3: Rationality

Defining *rationality* is the first step in constructing an itemized checklist for rationality. Rationality is defined here as our capacity to select and carry out our goals. Before rationality became self-conscious or reflexive, goal selection and execution were automated processes. Goals unencumbered by humanity's capacity to construct mythical goals were survival and flourishing, set within the limits of the environment. Humans share these goals with other organisms.

Because our large brains have given us the capacity for massive abstraction and imagination, we can now change the environment to suit our goals in ways that other animals do not. Our rationality now includes not only goal selection but the capacity to alter "naturally ordained" goals through rationality's reflexive function.

Like language (see Chomsky 2000) and morality (see Hauser 2006), rationality is both genetically and culturally endowed. As humans are capable of speech and moral behavior, so they are also capable of expressing rationality in the form of science. Here we use *science* in the sense of abstracting from experience to form guiding generalizations. (*Experience* includes mental as well as sensory phenomena—even the most theoretical mathematics is, after all, an experience.) As those generalizations begin to conform more precisely to the constraints of rationality itself, science begins to take on its modern mathematical form.

Rationality's constraints follow from its evolutionary function. The complex brain and its capacity for imagination and abstract thought augment our capacity for survival. A brain mapping and basing its behavior on selected patterns in its environment has a better chance of survival than an organism that reacts "blindly" to its circumstances through chemical signals or purely automated stimulus–response mechanisms.

Humans are gifted with the ability to externalize their mapping functions through the use of symbols. Symbols express their own survival capacities by triggering emotional responses that move us to replicate them—the memetic process. Symbols have emotional as well as semantic and syntactic meaning. We select symbol sets, theories, in part by reason of their capacity accurately to reflect our experience. Culture, education, and other experiences shape our rationality.

Rationality Checklist

Sub-Item 1: Semantic and Emotive Meaningfulness We are prompted to ensure the emotive, semantic, and syntactic force of the symbols we use to "re-present" experience (the first presentation was through the senses). Symbols used to present candidates for appropriate technology must in their net effect be emotionally compelling (Doorn and van de Poel 2011). Their semantic meanings, the networks of relations that tie them to experience, must be clearly understood. The ambiguity of symbols flows from their very etymology: "sym-bols" are literally "throwings together." Symbols acquire their meanings through (initial) acts of choice. The nature and limits of choices of symbols must be continually reviewed.

Sub-Item 2: Correspondence between a Technology's Theoretical Aspects and Its Tested Results Every proposal for an appropriate technology is conveyed through symbols, whether they are elements of ordinary spoken language or graphic representations such as blueprints. Those symbolic representations of a technology and its predicted consequences must be carefully mapped onto experience. The correlation of symbolic representation and experience is enshrined in what is called the correspondence theory of truth. One of the primary functions of the brain is to establish correlations between its states and those of the environment.

Sub-Item 3: Non-Contradictory Character of a Technology's Theoretical Elements A third prompting insists that theoretical proposals for appropriate technology cannot offer contradictory representations of experience. The primary instrument of rationality is reason. Reasoning most simply defined is the process of connecting experiences by means of abstract patterns. It would be "irrational" to claim that a thing "x" is connected to something else "y," and at the same time in the same way is not connected. This "law" of non-contradiction is so important in the history of thought that it serves as the foundation of the coherence theory of truth.

Sub-Item 4: Practicality or Effectiveness of a Technology A technology that cannot execute the purposes for which it is designed is an unacceptable project. Thinking itself has evolved by reason of its practical nature. The practicality of proposed projects is enshrined in the pragmatic theory of truth. This theory holds that it is never possible to know the truth in any absolute way. The best we can achieve is to hold beliefs that yield the consequences we aim to achieve (Emison 2004).

Sub-Item 5: Widest Possible Application of a Technology A fifth prompting demands that proposals for appropriate technology have the widest possible application. A technology that can perform multiple functions is to be favored over one that can execute a single function, other things being equal. This prompting follows from the conviction that our theories or technical proposals should cover the widest possible range of experience. The evolution of computers from calculating machines to multi-tasking devices is an example of this principle in action.

Sub-Item 6: Simplicity or Economy of a Technology: "Doing the Most with the Least" A sixth prompting is the truest test of the intellectual power of a technology proposal: KISS, or "Keep It Simple, Solomon." An engineer who can streamline a device so its every part is indispensable to its function is simply a genius. Thinking is itself the art of abstraction. Abstraction in its original sense is literally a "pulling apart" of a pattern from an experience. The simpler the pattern, the higher its degree of abstraction. The test of a pattern's simplicity is the number of symbols required for its representation. The fewer symbols required for a proposal's representation of experience, the more abstract the proposal. Translations of extreme abstractions into practical engineering projects may take decades. Even the early Einstein did not imagine that his $E = mc^2$ could yield the Manhattan Project.

Sub-Item 7: A Technology's Capacity to Stimulate Reexamination The seventh and final prompting springs from the conviction that no matter how good a technology is, there must be some way to improve on it. Technologies that by their very nature induce us to rethink the ways we think exemplify this checklist item.

None of the seven items on the rationality checklist are "make or break" items Compliance with checklist items cannot guarantee a technology's "perfect" rationality. For example, the theories underpinning a technology may be false, even if the technology itself works perfectly well. A proposal to drain a swamp to stop malaria's spread might follow from the hypothesis that "bad air" (the roots of the term *mal-aria*) is the cause of the disease. If the swamp were in fact the exclusive breeding ground of the anopheles mosquito, the technology would be practical. But the underlying theory would be false.

Rationality is a function of connectivity. The rationality of a technology can be measured by the numbers and kinds of connections that issue from its guiding principles. A technology may fit several items on the checklist and fail utterly on others. The items are intended as reminders rather than as strict rules for a technology's compliance. Particular evaluation metrics may not be pertinent in some cultural contexts and applications (Tharakan et al. 2006).

Item 4: Community Solidarity Does the proposed technology promote community solidarity in the best possible ways? Philosophers like Mo Di and Christ in East and West Asia have claimed that love or the bonding power of any community whether large or small is the primary human objective. From an evolutionary viewpoint, humans are incapable of surviving without community support.

Item 5: Freedom or Creativity Does a proposed technology enhance the freedom of the communities in which it is to be deployed? Here we use the term *freedom* to mean "freedom of choice." We have choices because of our rationality and capacity to reason—our power to abstract from unique experiences to form generalizations. Generalizations allow us to predict and thereby control the future. Imagination is also critical to generating choices. From an evolutionary point of view, freedom as the ability to create variation in our lives is a primary guarantee of our survival (Askland 2009; Marchant and Pope 2009).

Item 6: Pleasure Does a proposed technology enhance the pleasure of the communities in which it is to be deployed? We can give an evolutionary explanation of pleasure by saying it is a driving mechanism that points us in the direction of the behaviors necessary for the survival of the species.

Item 7: Introspection or Meditation Does a proposed technology enhance the capacity of its users to think about their thinking? Central and East Asian cultures affirm that meditation is a primary value. Meditation is perhaps best defined as the control of the attention by the attention. Our survival depends on paying attention to the right thing at the right time. Organisms that can control their attention through rational reflection can exert some measure of control over their survival.

An Appropriate Technology Checklist

We supplement the survival ethics checklist with an instrument to aid the transition from theoretical ethical judgments to practical engineering applications. Technologies that conform to the ethics checklist are judged to be *appropriate*. Appropriate technology has been a contentious issue since Schumaker (1989) decried mega-projects as the only route to improving the quality of life in the "third" worlds of the sixties. Developing the concept that "small is beautiful," he focused on community level needs. He proposed small scale, affordable technologies that would have an immediate impact on improving the health and well-being of under-developed communities. Rybczynski (1980) and others have debated appropriate technologies' contributions to sustainable development. While appropriate technology is not a panacea, it has demonstrated its potential to improve the quality of life when developed with community members as key players throughout the process.

In a community development context, we assess *appropriate technology* in light of the survival ethics checklist with emphasis on the derivative values of social justice and sustainability. We frame a set of questions that help evaluate the effects of a proposed technology. These questions should set a standard comparable to the environmental impact assessments that are now *de rigueur* for the implementation of any project. The questions must not be restricted to any particular set of issues. This open-ended approach will ensure that all issues that may be important in any given application context will be considered.

Checklist for Appropriate Technology Evaluation and Impact Assessment

1. Does the project require small or large amounts of capital?
2. Does the project emphasize the use of locally available materials?
3. Is the project going to be relatively labor intensive or is it going to be capital intensive?
4. What is the scale and affordability of the project/technology? Can individual families in the community afford it?
5. Does the context of the project require a scale that is local or global?
6. Is the project/technology understandable without high levels of training? Can it be controlled and maintained by local community members without specialized education?
7. Can the technology be produced in villages and/or small shops?
8. Will the project contribute to community members working together to improve the quality of life/standard of living?
9. Does the technology/project process include local communities in technology/project innovation, modification and implementation?
10. Is the technology adaptable and flexible? Can it be adapted to different places and changing circumstances?
11. Will the technology/project have an adverse impact on the environment?
12. Is the technology/project sustainable, both with respect to the environment and to technology repair and replacement when and if skilled professional support is no longer available?
13. Does the project/technology offer the opportunity and have the potential to enhance local, national, and global justice and equality?

The rationale for appropriate technology assessment springs from several perspectives. First and foremost, appropriate technology permits local needs to be met more effectively as community members become involved in identifying and addressing local community needs. Appropriate technology also implies that tools are developed to extend human labor and skills within the community, not to replace or eliminate them.

Furthermore, appropriate technology, relying on local materials and skills, represents a scale of activity that is comprehensible and controllable at the community level. Appropriate technology permits a more economical technology development and implementation process by eliminating long-distance transportation costs. In the same vein, it makes expensive, and sometimes unavailable, financial, transportation, education, advertising, management, and energy services unnecessary (McDonough and Braungart 2002).

With its emphasis on empowering local communities, appropriate technology helps establish a self-sustaining and expanding reservoir of skills within the community it seeks to serve, thus lessening economic, social and political dependency.

Appropriate technology is always situation-specific, depending on local community desires, geography, culture, location, availability of materials and other factors. Economic considerations are also critical. Judging appropriateness must reflect overall costs and benefits, including beneficiaries and payees.

However, non-economic criteria must play a large role in choosing appropriate technologies. Technological empowerment demands that technological choice be localized. And caution must be exercised with respect to institutional prejudices influencing technology choices.

Survival Ethics in Basic Science Research

Implementation of the survival ethics concept is not restricted to teaching situations in the classroom and field. Survival ethics can, and should, be included in the design of basic scientific research. Research that involves animal (e.g. IACUC, Institutional Animal Care and Use Committee) and human (e.g. IRB, Institutional Review Board) subjects in many countries must follow and be reviewed for compliance with basic standards (see, for instance, American Association for Laboratory Animal Science 2011). Compliance requires consideration of the validity and importance of the science to be conducted, as well as ensuring the protection of the rights and welfare of the research subjects themselves. Scientists must not only consider how their research will serve to benefit the survival of individuals ("Item 1: Survival" in the checklist above), but balance this against the costs of participants in the research study ("Item 2: Flourishing or Happiness"). The balance between the two is achieved largely by successful rationalization of these two items (see "Item 3: Rationality"). Faculty at Howard University utilize this basic approach to train graduate students to develop and submit IACUC and IRB applications for their research. They also incorporate this approach in undergraduate classes as well. Science & Public Policy, an undergraduate course in Biology, focuses on the intersection of these two disciplines within an ethical framework—grounded in the balancing of the development of a rational cost-benefit analysis of research.

Part III. Survival Ethics in Engineering Practice Applying the Checklist Model in the Field

Howard University faculty take the multi-disciplinary team approach into the field in collaboration with students from the Howard chapter of Engineers Without Borders for projects in Salvador in Bahia, Brazil, and in Choimim in the Nandi Hills, Kenya. The team supervises a 45,000 liter rainwater capture and storage installation and water monitoring system for two orphanages, three schoolhouses, and a student hostel in Choimim.

The survival ethics checklist items guide both the selection of project sites and appropriate technology applications. While children's needs for food, healthcare, and education were adequately addressed in Choimim, water access was intermittent and insufficient. A rainwater-capture system used local materials and labor to solve the problem.

Demonstrating the integration of faculty research with education and service-based learning and community development, Howard faculty and students also use the team approach on a NOAA/NSF (National Oceanic and Atmospheric Administration/National Science Foundation) climate assessment project in Kawasara, Senegal. The team supervises a solar electrification project that supplies 55 villagers with lighting, cell phone charging and television power sources without incurring fuel costs (Tharakan et al. 2008; Tharakan 2011). Conventional planning suggested the use of diesel electric generators to supply power for a solar flux tower to be sited near the remote village. However, reflection on checklist items provoked reconsideration. Would it be ethical to supply power to the tower and not to the village? Even if generators with the capacity to supply both the tower and the village could be procured, the villagers would not be able to pay their share of fuel costs. However, they would be able to pay for their share of maintenance and long-term replacement costs for a solar facility. Solar-powered lighting provides increased opportunities for education, and solar-powered refrigeration enables long-term storage of vaccines and other medicines.

University of Puerto Rico/Mayagüez engineering faculty and students have established partnerships with Caribbean communities serving peoples of Spanish, French, and native/aboriginal descent. Ethics checklist items direct UPRM efforts to serve economically disadvantaged communities through service learning projects. For example, the YouthHaiti project uses checklist items to define sustainable development in projects in the village of Duchity in Sud, Haiti. Developed through a community based decision-making process, the projects include dry composting toilets, an upgraded water system and appropriate renewable energy systems such as micro hydro-electric and wind turbines. UPRM faculty and students as well as Duchity community members are developing learning modules that can be introduced in K-12 curricula to provide a general understanding of different renewable energy sources and stimulate job creation while promoting resource conservation. The community based decision-making process and learning modules are integral to the checklist item of community bonding.

Inspired by checklist items, course faculty from Howard and UPRM among others have created an International Network on Appropriate Technology (INAT).

A series of conferences on appropriate technology in Zimbabwe, Rwanda and Ghana culminated in the development of INAT as an interdisciplinary global consortium of academics and practitioners who offer their expertise to communities seeking to adopt new technologies or new applications of existing technologies in developing areas (Mhlanga and Trimble 2004; Muchabayiwa et al. 2006; Tharakan et al. 2008; Tharakan and Trimble 2008; Dzidzeniyo et al. 2010). Through INAT our incorporation of survival ethics into technology assessment has been presented to engineering faculty in a number of countries including Kenya, North Sudan, Senegal, Ghana, Rwanda, Zimbabwe, South Africa, Puerto Rico, Trinidad and Tobago, Suriname and Brazil (Tharakan 2011).

The Network joins with established technology centers that have developed their own mission statements and international projects. Roy's Barefoot College project in the village of Tilonia in the state of Rajasthan, India provides 6 months of training to semi-literate grandmothers to enable them to install and maintain solar lighting systems and rainwater storage tanks for their remote villages in India, and Bhutan as well as numerous countries in Africa and South America (Roy and Hartigan 2008; O'Brien 1998). The survival ethics checklist dictates that Barefoot College projects be sited in remote villages whose basic survival needs are already met. Emphasis on solar lighting springs from the consideration that rationality is a prerequisite for flourishing just as education is a prerequisite for rationality. Solar lighting makes possible night schools for children and adults whose work schedules do not permit them to attend classes during daylight hours. Rainwater-capture tanks free villagers from the time-consuming task of carrying water over long distances to their homes, thereby providing more leisure time for education.

Most recently, the Barefoot College partnered with a Sudanese INAT member and several NGOs to train four rural women from Sudan to be solar engineers in their communities (Kadoda 2009). In February 2011 these women completed the installation of solar panels, batteries, and lighting for 98 homes in the village of Mirri in the Nuba Mountains in western Sudan. They also supervised the construction of a rainwater capture and in-ground storage system for the village school.

Sadly, however, ethics and politics do not mix well in the Nuba Mountains. Recent fighting broke out after a dispute over state election results just a month before the declaration of independence of South Sudan from the North. The still ongoing war killed or drove the Mirri villagers into exile and halted the project from extension into the next village (Aldorod) targeted by the project for solar electrification. Bombs destroyed rainwater capture tanks and solar lighting equipment. What was not destroyed was looted. It is worth noting, however, that the team of barefoot solar engineers comes from the two villages which are politically aligned on opposing sides. For a time, the project appeared to be bringing the two communities closer. Survival ethics must be a tenuous proposition in war-torn areas.

What further educational development must take place to test technology and policy applications for compatibility with survival ethics? The initial step is to involve communities that will be affected by proposed technology applications. To exercise their own judgment, community members require an elementary grasp of the science and engineering principles supporting applications. In the best case, their education will enable them to participate fully in deploying and sustaining applications. This task cannot be accomplished without professional assistance from social science field researchers conversant with the cultures in whose environments the proposed technologies are to be deployed.

Informed community members should have an important role in directing research in technology toward survival. Currently, government and business sector funding heavily influences research directions (Sclove 1998). To counter this imbalance, the Netherlands developed a model for giving local communities a greater voice in the direction of science and engineering research. The government mandates federally funded universities to set up "Science Shops" in university neighborhoods to address community issues by providing advice and setting up research teams to solve problems (Roush 1996). This model includes public education in science and engineering. It has spread throughout Europe and Canada (European Commission on Community Research, "Science Shops—Knowledge for the Community") and deserves to be tested in the Global South with results disseminated through the UNESCO Ethics of Science and Technology Program (Henk 2010).

In India, the Kerala Sastra Sahitya Parishad (KSSP) uses street theater, workshops and traveling shows to publicize scientific issues and educate rural and other under-served communities about critical scientific, environmental and policy issues. The KSSP's Integrated Rural Technology Center develops or adapts technologies for rural needs.

Educating ethicists, scientists, engineers, and community members to make multi-disciplinary assessments of proposed technologies cannot forestall all harmful technologies. Nevertheless, the awareness of the social responsibility of scientists and engineers, and the exposure of ethicists and community members to important technical aspects can provide a context in which solutions to real community problems will emerge from technology innovation.

An in-depth analysis of survival ethics heuristics in a multidisciplinary context can help future engineers to know how and when to best "incorporate social elements into a comprehensive systems analysis of their work" (National Academy of Engineering, 2004). It is the duty of each scientist, engineer and ethicist to embrace the social responsibility that each profession entails and move into action with community members to better guide the direction of technology innovation. Inaction betrays all those who may follow us on the planet.

Acknowledgments This research was supported in part by the following: U.S. Department of Education, Fund for the Improvement of Post Secondary Education, P116N060032: Ethical and Public Policy Issues in the Sciences; National Science Foundation (NSF), PHY 1033028 MPS: Graduate Research and Education for Appropriate Technology; NSF DUE 9952448 CCLI: Environmental Studies Curriculum Development; NSF DBI 0405151 UMEB: Howard University Environmental Biology Scholars; NSF DBI 9423947 REU: Ecological Research in the Southwestern U.S. and its Relevance to Environmental Policy.

References

American Association for Laboratory Animal Science. (2011). http://www.iacuc.org. Accessed October 23, 2011.

Appiah, A. (2008). *Experiments in ethics*. Cambridge: Harvard University Press.

Askland, A. (2009). Science and socially responsible freedom. *Science and Engineering Ethics, 15*(3), 343–349.
Axelrod, R. (2006). *The evolution of cooperation*. New York: Basic Books.
Barefoot College, Tilonia, Rajasthan, India, http://barefootcollege.org/. Accessed June 20, 2011.
Blackburn, S. (1993). *Essays in quasi-realism*. New York: Oxford University Press.
Bouville, M. (2008). On using ethical theories to teach engineering ethics. *Science and Engineering Ethics, 14*(1), 111–120.
Bullock, M., & Panicker, S. (2003). Ethics for all: Differences across scientific society codes. *Science and Engineering Ethics, 9*(2), 159–170.
Catalano, G. (2004). Senior capstone design and ethics: A bridge to the professional world. *Science and Engineering Ethics, 10*(2), 409–415.
Cerutti, F. (2010). Defining risk, motivating responsibility and rethinking global warming. *Science and Engineering Ethics, 16*(3), 489–499.
Chan, W. (1963). *A source book in Chinese philosophy*. Princeton: Princeton University Press.
Chomsky, N. (2000). *On nature and language*. New York: Cambridge University Press.
Davis, M. (2003). What's philosophically interesting about engineering ethics? *Science and Engineering Ethics, 9*(3), 353–361.
Davis, M. (2006). Integrating ethics into technical courses: Micro-insertion. *Science and Engineering Ethics, 12*(4), 717–730.
Diamond, J. (1999). *Guns, germs and steel: The fates of human societies*. NY: W.W. Norton.
Diop, C. (1991). *Civilization or barbarism*, Y. M. Ngemi (Trans.). Chicago: Lawrence Hill.
Doorn, N., & van de Poel, I. (2011). Editor's overview: Moral responsibility in technology and engineering. *Science and Engineering Ethics*, doi:10.1007/s11948-011-9285-z.
Dzidzeniyo, V., Hansen, E., Fortunak, J., Tharakan, J., & Trimble, J. (Eds.) (2010). *Proceedings of the 4th international conference on appropriate technology*. Kumasi, Ghana: Kwame Nkrumah University of Science and Technology.
Eisenbarth, S., & Van Treuren, K. (2004). Sustainable and responsible design from a Christian worldview. *Science and Engineering Ethics, 10*(4), 23–429.
Emison, G. (2004). American pragmatism as a guide for professional ethical conduct for engineers. *Science and Engineering Ethics, 10*(2), 225–233.
European Commission on Community Research, "Science shops—Knowledge for the community," http://ec.europa.eu/research/science-society/pdf/science_shop_en.pdf. Accessed June 19, 2011.
Fleischmann, S. (2004). Embedding ethics into an engineering curriculum. *Science and Engineering Ethics, 10*(2), 369–381.
Gardiner, S. (2011). *A perfect moral storm: The ethical tragedy of climate change*. NY: Oxford University Press.
Gawande, A. (2009). *The checklist manifesto: How to get things right*. NY: Metropolitan.
Graber, G., & Pionke, C. (2006). A team-taught interdisciplinary approach to engineering ethics. *Science and Engineering Ethics, 12*(2), 313–320.
Graduate Education for Research and Appropriate Technology, http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=1033028. Accessed October 26, 2011.
Graedel, T., & Allenby, B. (1995). *Industrial ecology*. Englewood Cliffs, N.J.: Prentice Hall.
Greene, J. (2003). From neural "is" to moral "ought": What are the moral implications of neuroscientific moral psychology? *Nature Reviews Neuroscience, 4*, 847–850.
Greene, J., Sommerville, R., Nystrom, L., Darley, J., & Cohen, J. (2001). An fMRI investigation of emotional engagement in moral judgment. *Science, 14*, 2105–2108.
Haidt, J. (2007). The new synthesis in moral psychology. *Science, 18*, 998–1002.
Harris, C. (2004). Internationalizing professional codes in engineering. *Science and Engineering Ethics, 10*(3), 503–521.
Harris, C. (2008). The good engineer: Giving virtue its due in engineering ethics. *Science and Engineering Ethics, 14*(2), 153–164.
Harris, S. (2010). *The moral landscape: How science can determine human values*. New York: Press.
Hauser, M. (2006). *Moral minds: How nature designed our universal sense of right and wrong*. New York: Harper Collins.
Haws, D. (2004). The Importance of meta-ethics in engineering education. *Science and Engineering Ethics, 10*(2), 204–210.
Henk, A. (2010). UNESCO's activities in ethics. *Science and Engineering Ethics, 16*(1), 7–15.

Hornung, E. (1971/1982). *Conceptions of god in ancient Egypt: The one and the many*. J. Baines (Trans.). Ithaca, New York: Cornell University Press.
International Network on Appropriate Technology (INAT), http://www.appropriatetech.net. Accessed June 20, 2011.
Joyce, R. (2001). *The myth of morality*. Cambridge: Cambridge University Press.
Joyce, R. (2006). *The evolution of morality*. Cambridge: MIT Press.
Kabo, J., & Baillie, C. (2009). Seeing through the lens of social justice: A threshold for engineering. *Science and Engineering Ethics, 34*(4), 317–325.
Kadoda, G. (2009). *Habboba* (grandmothers') new knowledge: Perspectives from the barefoot solar engineers project in the Nuba Mountains of Sudan. 4th WAAD (Women in Africa and the African Diaspora) International Conference, Abuja, Nigeria, August 3-8.
Kaiser, J. (2010). Oversight but no strict rules for synthetic biology. *Science, 26*, 1166.
Keefer, M. (2005). Making good use of online case study materials. *Science and Engineering Ethics, 11*(3), 413–429.
Kerala Sastra Sahitya Parishad, http://www.kssp.in/. Accessed June 19, 2011.
Kintisch, E. (2009). Projections of climate change go from bad to worse, scientists report. *Science, 20*, 1546–1547.
Kintisch, E. (2010). Scientists grapple with 'completely out of hand' attacks on climate science. *Science, 26*, 1070.
Lekka-Kowalik, A. (2010). Why science cannot be value-free: Understanding the rationality and responsibility of science. *Science and Engineering Ethics, 16*(1), 33–41.
Locke, A. (1991). *The philosophy of Alain Locke: Harlem renaissance and beyond*. Philadelphia: Temple University Press.
Lozano, J., Palau-Salvador, G., Gozálvez, V., & Boni, A. (2006). The use of moral dilemmas for teaching agricultural engineers. *Science and Engineering Ethics, 12*(2), 327–334.
Mackie, J. (1977). *Ethics: Inventing right and wrong*. NY: Penguin.
Marchant, G., & Pope, L. (2009). The problems with forbidding science. *Science and Engineering Ethics, 15*(3), 375–394.
Martin, M. (2006). Moral creativity in science and engineering. *Science and Engineering Ethics, 12*(3), 421–433.
McDonough, W., & Braungart, M. (2002). *Cradle to cradle: Remaking the way we make things*. New York: North Point Press.
Mhlanga, S., & Trimble, J. (2004). *Proceedings of the 1st international conference on appropriate technology*. Bulawayo, Zimbabwe: Ministry of Science and Technology.
Miller, G. (2008). The roots of morality. *Science, 9*, 734–737.
Monk, J. (1997). Good engineers. *European Journal of Engineering Education, 22*(3), 235–248.
Muchabayiwa, B, Trimble, J., & Dube, S. (Eds.) (2006). *Proceedings of the 2nd international conference on appropriate technology*. Bulawayo, Zimbabwe: Ministry of Science and Technology.
National Academy of Engineering of the National Academies. (2004). *The engineer of 2020: Visions of Engineering in the New Century*. Washington, D.C.: The National Academies Press.
O'Brien, C. (1998). *Education for sustainable community development: Barefoot college, Tilonia, India.* Dissertation, McGill University.
Passino, K. (2009). Educating the humanitarian engineer. *Science and Engineering Ethics, 15*(4), 577–600.
Pinker, S. (2011). *The better angels of our nature: Why violence has declined*. New York: Viking Press.
Provonost, P., & Vohr, E. (2010). *Safe patients, smart hospitals: How one doctor's checklist can help us change healthcare from the inside out*. NY: Hudson Street Press.
Pustovit, S., & Williams, E. (2010). Philosophical aspects of dual use technologies. *Science and Engineering Ethics, 16*(1), 17–31.
Radhakrishnan, R., & Moore, C. (1967). *A source book in Indian philosophy*. Princeton: Princeton University Press.
Rawls, J. (1971). *A theory of justice*. Cambridge: Belknap Press.
Ridley, M. (1998). *The origins of virtue: Human instincts and the evolution of cooperation*. New York: Penguin Books.
Roush, R. (1996). Scientific community: U.S. joins "science shop" movement. *Science, 2*, 572–573.
Roy, B., & Hartigan, J. (2008). Empowering the rural poor to develop themselves: The barefoot approach (Innovations case narrative: barefoot college of Tilonia). *In Innovations: Technology, Governance, Globalization, 3*, 67–93.

Rybczynski, W. (1980). *Paper heroes: A review of appropriate technology*. NY: Anchor/Doubleday.
Schumaker, E. (1989). *Small is beautiful*. NY: Harper Perennial.
Sclove, R. (1998). Better approaches to science policy. *Science, 27*, 1283.
Son, W.-C. (2008). Philosophy of technology and macro-ethics in engineering. *Science and Engineering Ethics, 14*(3), 405–415.
Staub, E. (1989). *The roots of evil: The origins of genocide and other group violence*. Cambridge: Cambridge University Press.
Stieb, J. (2011). Understanding engineering professionalism: A reflection on the rights of engineers. *Science and Engineering Ethics, 17*(1), 149–169.
Tharakan, J. (2011). Institutionalizing a student-centered community-based service learning engineering education experience. In *Proceedings of the international engineering and technology education conference (IETEC 2011),* Kuala Lumpur, Malaysia, January.
Tharakan, J., & Trimble, J. (Eds.) (2008). *Proceedings of the 3rd international conference on appropriate technology*. Kigali, Rwanda: Ministry of Science and Technology.
Tharakan, J., Castro, M., Trimble, J., Schwartzman, D., Stephenson, B., Broome, T., et al. (2006). Diversifying engineering education: A seminar course on the ethics and the philosophy of appropriate technology. *Global Journal of Engineering Education, 9*(2), 111–119.
Tharakan, J., Mitchell, M., Moore, J., & Jenkins, G. (2008). Design of a combined solar energy system for a remote flux tower and a rural community. In J. Tharakan, & J. Trimble (Eds.), *Proceedings of the 3rd international conference on appropriate technology* (pp. 51–58). Kigali, Rwanda: Ministry of Science and Technology.
Turner, T. (2001). *Controlling pilot error: Checklists and compliance*. NY: McGraw-Hill Professional.
UNESCO Social and Human Sciences, Ethics of Science and Technology Program, http://www.unesco.org/new/en/social-and-human-sciences/themes/ethics-of-science-and-technology/science-and-technology/. Accessed June 19, 2011.
United Nations. (1948). Universal Declaration of Human Rights. http://www.un.org/en/documents/udhr/index.shtml, Accessed June 21, 2011.
Varner, G. (2008). Utilitarianism and the evolution of ecological ethics. *Science and Engineering Ethics, 14*(4), 551–573.
Verharen, C. (2006). Sage philosophy, rationality and science: The case of Ethiopia. *Ethiopian Journal of the Social Sciences and Humanities, 4*(2), 13–32.
Verharen, C. (2008a). Comparing ancient Egyptian and Oromo Philosophy. *Journal of Oromo Studies, 15*(2), 1–31.
Verharen, C. (2008b). Survival ethics: Consequences for appropriate technology. In J. Tharakan, & J. Trimble (Eds.), *Proceedings of the 3rd international conference on appropriate technology* (pp. 268–274). Kigali, Rwanda: Ministry of Science and Technology.
Verharen, C., & Tharakan, J. (2010). Barefoot ethics: Social justice through an appropriate technology checklist. In Dzidzeniyo, V., Hansen, E., Fortunak, J., Tharakan, J., & Trimble, J. (Eds.), *Proceedings of the 4th international conference on appropriate technology* (pp. 36–42). Kumasi, Ghana: Kwame Nkrumah University of Science and Technology.
Veslind, P. (2001). Engineering as applied social science. *Journal of Professional Issues in Engineering Education & Practice, 127*(4), 184–189.
Vogel, G. (2004). The evolution of the golden rule. *Science, 20*, 1128–1131.
Wrangham, R. (2004). Killer species. *Daedalus, 133*(4), 25–35.
Zandvoort, H., van Hasselt, G., & Bonnet, J. (2008). A joint venture model for teaching required courses in 'ethics and engineering' to engineering students. *European Journal of Engineering Education, 33*(2), 187–195.