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TABLE OF CONTENTS

Integration of Indigenous Knowledge Systems into Appropriate Technology Development

John Tharakan
Department of Chemical Engineering, Howard University
2300 6th Street, NW, LKD 1009, Washington, D.C. 20059, USA
FAX(202)806-4635, E-mail: jtharakan@howard.edu

Abstract

Appropriate Technology (AT) implementation should result in community empowerment, independence and sustainability. AT success depends on engagement and support of impacted community through entire technology conceptualization, development and implementation process. Sensitivity to socio-cultural context and respect for local knowledge is critical. This is part of Indigenous Knowledge Systems (IKS), which developed prior to modern scientific knowledge system (MSKS), following colonialism and "western" education. IKS are broad and diverse, including from ancient India, China and the African continent. They address issues in agriculture, food processing and preservation, water, health, and other areas of need. IKS, context-specific intellectual resources, must be integrated into AT identification and evaluation. We examine selected IKS for agriculture, food processing and water, including specific examples from Sudan and India, where indigenous technologies have been implemented for sustainable development. MSKS have not exploited IKS for rural development. Many AT's for developing communities have roots in IKS and have been implemented. However, IKS remains largely untapped, as intellectual resource and knowledge base. Exploitation of IKS could provide needed "innovation" for AT for sustainable development. IKS must be validated and then integrated into AT implementation. This validates local community practices, provides context-specific starting points for development, and has greater probability of success.

Keywords: Indigenous, Knowledge Systems, Modern Scientific Knowledge, Appropriate Technology, Sustainable Development

Indigenous Knowledge Systems

Indigenous Knowledge (IK) and Indigenous Knowledge Systems (IKS) are terminologies utilized by researchers and scholars to broadly capture bodies of knowledge and knowledge systems that are localized and unique to a given culture or society (Ellen and Harris, 1996; Ahmed, 1994). IK and IKS are comprised mostly of a local community and society's "hands-on" "know-how", "do-how" and accumulated experience that would include both locally generated, as well as externally borrowed and/or adapted knowledge (Ahmed, 1994). It is characterized and made unique by the cultural, social and ideological context within which it is found. IK and IKS are engendered and developed through specific sociological, ecological, and geographic conditions, as well as biological, cultural and climactic conditions unique to the indigenous culture in which the IK is situated. As argued by Warren (1991), this IK is the information base for a given society, critical to the facilitation of communication and decision-making, such as the *panchayathi raj* system in rural India (Mahesh, 2011). Whether we are talking about indigenous agricultural knowledge (IAK) (Titilola, 1990) or indigenous technical knowledge (ITK) (Biggs and Clay, 1981), IK is always unique to a given culture and society. IKS can encompass and span the scale from small indigenous communities to national systems such as *Ayurveda*[1] and

[1] Ayurveda (Sanskrit: आयुर्वेद; *Āyurveda*, "the complete knowledge for long life") or ayurvedic medicine is a system of traditional medicine native to India and a form of alternative medicine. http://en.wikipedia.org/wiki/Ayurveda; Accessed Sep 21, 2014

Unani[2], while some IKS have gained global acceptance, such as acupuncture (Hsu, 1996). It is important to note that IK and IKS are separate and different from modern scientific knowledge systems (MSKS) or the "international knowledge systems" which includes knowledge generated by universities and research institutions. "International knowledge" is created from modern scientific research and development, which are all part of the global scientific and technological enterprise of human civilization. Unlike IK and IKS, which tend to be orally based and transferred, MSK can only be acquired through formal education ("book learning") and it is enhanced by advanced study, training and mentoring that ensure extant processes for scientific knowledge creation, affirmation and dissemination are maintained. Thus, the dominant paradigms of MSKS are re-affirmed and reinforced often at the expense and devaluation of IKS.

However, as discussed in an earlier paper (Tharakan, 2012a, 2012b), IK and IKS are often hard to uniquely define and categorize because "indigenous" is a politically "loaded" term, where defining what and who is "indigenous" can be a delicate exercise in minimizing the diversity of people that would be offended or antagonized, either by being referred to as indigenous or not being included in the "indigenous" grouping. Nevertheless, various appellations for this broad well of knowledge have been recognized, proposed and articulated, including, in addition to ITK and IAK, ethno-ecology, local knowledge, folk knowledge, traditional knowledge, traditional environmental (or ecological) knowledge (TEK) and people's science (Warren, 1991).

In general, IKS do not often have substantial "theoretical" grounding, but IK is not static. IK can be constantly changing, being produced, reproduced, discovered, lost, and expanded as communities prevail, flourish and engage in exchanges across their boundaries. IK is shared much more than global science, with its current focus on intellectual property – hence IK is seen as `people's science'. Also, because of it's rooting in local culture and tradition, distribution of IK is usually asymmetrically segmented within a population, with the segmentation usually dependent on the type of knowledge. Hence, IKS are usually preserved and transmitted through "special" individuals, acknowledged as such through experience, ritual or political authority. IKS are also situated within broader cultural traditions and one cannot easily separate technical from non-technical knowledge and practices (Flavier et al, 1995). Most importantly, IKS are dynamic, continually influenced by internal creativity and experimentation in response to social, environmental, and public health and safety stressors, allowing for growth and development of IKS.

Appropriate Technology

The widespread use of the term "appropriate technologies" requires articulation of what exactly it means for a technology to be deemed "appropriate". AT has always been difficult to define, and AT's development and implementation have been a source of debate in the past (Rybzynski, 1991). Over the decades, discourse and discussion on AT and what exactly characterizes it, some consensus has emerged on what AT means, but many of the received wisdoms about AT are still being questioned (Lissenden et al, 2014). Some general received knowledge about AT suggests that it should only require small amounts of capital, emphasize the use of local materials, be relatively labor intensive and be small scale and affordable. However, as the discussion on micro-AT and macro-AT has emerged, these tenets are still being questioned. AT philosophy requires that it be grounded within specific communities, and that AT development and implementation engage these communities resulting in capacity building and empowerment. Thus, AT's must, in general, be comprehensible, controllable and maintainable within a community. More capital intensive, "sophisticated" and imported technologies often require high levels of technical education and training for maintenance and operation, not usually resident within local communities, and the lack of which often results in the failure of an AT.

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[2] Unani-tibb or Unani Medicine also spelled Yunani Medicine (/juːˈnɑːni/; *Yūnānī* in Arabic, Hindi-Urdu and Persian) means "Greek Medicine", and is a form of traditional medicine widely practiced in South Asia. http://en.wikipedia.org/wiki/Unani; Accessed Sep 21, 2014.

Perhaps most importantly, adherence to the ethic of AT requires that local communities must be included at all stages, from technology conceptualization and innovation to development and implementation. Any technology that claims the mantle of "appropriate" should also be adaptable and flexible, while eliminating – or at least minimizing - adverse environmental impacts (Darrow and Saxenian, 1986; Tharakan, 2006).

Indigenous Knowledge Systems and Sustainable Development

The World Bank (WB) launched the Indigenous Knowledge for Development program (World Bank, 2004), acknowledging and recognizing the outcomes of the First Global Knowledge Conference (held in Toronto in 1997) where civil society stakeholders called on the WB to not only become a knowledge bank sharing 50 years of "development" experience, but to incorporate into the knowledge bank "community-based knowledge systems" cataloguing where successful local solutions for local development problems had been implemented. The WB disseminated a series of Indigenous Knowledge Notes, which comprised (at that time, 2004) over sixty thematic short papers that introduced various case studies, synthesizing lessons learned and discussing the impact IK could have on development efforts. These, in the case of the WB, are specifically tied to achieving the Millennium Development Goals (MDG's). The case studies presented demonstrated how communities across Africa and Asia used IKS to empower themselves. The WB IK notes spanned the spectrum of development activities, including IK practices to help increase crop yields, educate children, reduce suffering from HIV/AIDS, decrease infant and maternal mortality, heal the impact of conflict, and learn from each other. What was notable about the cases reported was the demonstration that local communities were eager to combine MSKS and current technology with their own IK and cultural institutions to improve the overall efficacy of development products, processes and services resulting in improved outcomes as far as the millennium development goals (MDG's) were concerned, such as the use of walkie talkies by traditional birth attendants in Uganda to significantly reduce maternal mortality, application of the traditional judicial systems in Ghana to reduce conflict, self-empowerment and capacity building for rural women in India, youth capacity building in Senegal resulting in improved skills and competitiveness, and enhancing the effectiveness of HIV/AIDS projects by cooperation with traditional healers.

Indigenous Knowledge Systems in Africa

The IK Notes in the WB document span development issues across a wide spectrum of technology areas as well as across the African continent, including an overview of sub-Saharan Africa and some example from South Asia. Sustainable IKS from Zimbabwe for agriculture demonstrate their intrinsic value for secure and sustainable food production, as well as for cultural rights. In Ghana, IKS for organic farming practices, literacy and local governance, treatment and management of HIV/AIDS, indigenous philosophical approaches for conflict management, and *Adzina*, the indigenous systems for trial by jury show the astonishing breadth of IKS. In Senegal, IKS for finance and banking, grassroots democracy, language and literature and women's rights and empowerment underscore the value of IKS. In Mali, IKS supported development of agricultural unions to increase local empowerment, provided cultural resources for maternal health, engaged community, culture and language for self-management, and was integrated into the implementation of new technologies and practices, enhancing sustainable development. In Burkina Faso, IKS on rainfall forecasting have been integrated into modern scientific rainfall forecasting.

Across the continent in Uganda, IKS facilitates the engagement of a community in the development, implementation *and acceptance* of a tele-center for information and communications, the development of indigenous vegetables for household food security, and the incorporation of traditional medical practices in promoting public health. In Tanzania, IKS have been instrumental in enhancing agricultural output by engaging indigenous farming knowledge in agriculture and in promoting local seed fairs that increase agricultural sustainability. In Ethiopia, validation of IKS has promoted public health through traditional medicines and social insurance schemes. In Eritrea, engagement of elders and traditional health providers with acknowledgement of the validity of their approach facilitated reduction of female genital mutilation (FGM) incidence, as well as increased awareness of FGM's harmful long- term effects on female reproductive health. IKS has also been instrumental in providing care and assistance to war victims in Mozambique, demonstrating value in healing the ravages of war. In India, IKS have been validated and deployed to increase agricultural productivity, amongst others.

The IK Notes also provide much needed overviews of IKS in particular contexts, as well as the critical analyses that demonstrate the value of integrating IKS into development, especially how this enhance sustainability through validation of local rituals and practices. Most importantly, the value of IKS in the context of MSKS and intellectual property shows the importance of protecting IKS from theft and exploitation of generations of experience at the local level for private gain. A crucial South-South engagement between East Africa and South Asia demonstrates the value of IKS to promote community literacy, capacity and sustainable development.

What is clear from the IK notes of the WB is that there are no set blueprints, cookie-cutter recipes or shortcuts to development. It is important, however, not to romanticize IKS. Nor is it useful to suggest that MSKS is irrelevant. What is critical to understand is that IKS, hand-in-hand with MSKS, can work together democratically and with self-determination within individual cultures and communities in a context-specific manner to foster sustainable development.

These efforts on the part of this key multilateral institution for global development follow from the still-contentious tension between IKS and MSK. As Agarwal (1995) has pointed out, much recent discourse has posited that IKS can be a significant resource for development, which is viewed as problematic due both to the conceptualization of IKS and the unquestioned use of IKS for development; to productively engage IKS in development, the dichotomy between IKS and MSKS needs to be overcome, focusing more on "autonomy" for indigenous peoples. This needs to be done through increased efforts to integrate MSKS into IKS validating it and community capabilities.

Indigenous Knowledge Systems in Sudan

The use of IKS for sustainable development has gained much traction from initial efforts two decades ago (Boon and Henz, 2007). For example, in a comprehensive study on IKS in the Sudan, Ahmed (1994) provides a review of IK in Sudan and its critical role in sustainable development efforts. Sustainable development here encompasses natural resource management, balancing population growth and resource extraction, addressing issues of inequality and rising levels of poverty, reducing non-renewable energy and resource consumption, enhancement of renewable energy resource development, and most importantly and pertinent to this paper, sustainable development has to pay special attention to local communities and engage them in all development efforts. IKS in Sudan has a long history within ancient cultures and communities from across this large country. These range from indigenous fermented foods and beverages from the different rural areas of Sudan, traditional knowledge for wildlife conservations, utilization of traditional mud bins for preserving and storing grain, as well as traditional water harvesting techniques of northern Darfur that increased food security in that region at that time. Contemporaneous to the work from Sudan, DeWalt (1994) has demonstrated IKS incorporation into enhancing agricultural output and productivity in various contexts.

Indigenous Knowledge Systems in Kerala, India

In the south Indian state of Kerala, specifically in North Malabar, Sreekumar et al (2006) have shown that local agriculture has benefited from integration of ITK into modern farming practices. Hence, ITK requires documentation and conscious promotion for a more sustainably oriented perspective on agriculture, including validation through the MSKS. The ITK of North Malabar, derived from local culture, traditions and rituals, are founded in local communities long-term interaction with the environment, underscoring the dynamic nature of ITK, which is tightly interwoven with the local communities beliefs, norms and culture. In the context of globalization, farmers are forced to choose crops and enterprises that suit market opportunities, which thus invariably bring about changes in established farming techniques, and land and water utilization, reinforcing the dynamism of ITK. It includes experimentation to adjust to new crops and cultivation regimens. Safeguarding this evolving ITK requires documentation, but also engagement of MSKS from agricultural research and development agencies in collaboration with local farming communities. This validation of ITK, and integration of MSKS through governmental and multilateral institutions, can enhance development of appropriate technologies for sustainable development of agriculture.

Scholars, practitioners and development professionals across the globe have for long now understood the value of IKS and written on and underscored the critical importance of local community engagement at all levels and in all areas of endeavor to enhance sustainability of development projects. Chadwick et al (1998) have provided a comprehensive analysis and review of IKS pertaining specifically to water resource management in Bangladesh. The review focuses on IK used in natural and water resource management within the wider context of livelihood systems, including fisheries, navigation, water uses, health, hygiene and sanitation, and agriculture, principally irrigation and soil and water conservation. This work identifies locally developed and adapted technologies for potential implementation in the field, as well as identifying institutional and policy settings conducive to IKS integration in sustainable water resource management strategies. Policy makers and development planners are increasingly aware of the important role ITK plays in promotion of sustainable development. Clearly, we can learn from those who survive and adapt to local ecological conditions. This knowledge can be the basis for identifying ecologically sustainable equitable options for resource use. Although the initial focus of IKS study was agricultural production this perspective has expanded to cultural knowledge producing mutual understanding and identity among the members of farming communities, inextricably linking ITK with cultural, ecological and sociological factors.

It is important to emphasize that IKS are structured by the systems of classification and management that govern resource use, and fuelled by observation, experimentation and innovation of these community members (Fernandez, 1994). Moreover, it is accessible to, and developed within the framework of, those members of society who are responsible for that aspect of resource management and production, and as such, IK is by its very nature gender sensitive (Warren et al, 1995). For example, in Bangladesh as is often the case in many developing countries with water scarcity, women are traditional "water providers" and managers. The women have thus developed a wide range of indigenous strategies to obtain, purify and preserve water, and to use it frugally.

Institutionalizing IKS for Appropriate Technology Development

A number of important lessons have been learned in terms of appropriate means of institutionalizing IK. Such processes are critical to development of integrated water resource management strategies. These processes fail when they do not take into account that civil institutions do not always adequately represent all stakeholders. A simplistic viewing of agriculture and farmers as the only water users also contributes to failure. However, the main reason behind projects failing is the lack of engagement and participation of the local community in initial stages of project design and planning, where it is most critical. Many questions need to be addressed in the integration of IKS into AT and sustainable development. Have already existing institutions, both formal and informal, been resolving such problems before? Would they be better placed to resolve these? Do they do so in an equitable manner or do they, as some claim is the case of the project's participatory institutions, invariably benefit the rich? Furthermore, does the system have any mechanism where it can identify and build in indigenous knowledge of water management which could be properly assessed and avoid immediately looking to a “western engineering solution'? For instance, many local populations have long and well-developed tradition of water resources management in rural areas, traditions that involve both sophisticated systems of collective action, locally developed technical knowledge as well as systems of payment. Thus, for organizations and projects to facilitate participation, there is a requirement that their own procedures, style and culture be transparent, participatory and engaging of the local and impacted communities. The changes required in organizations are more often than not reversals, from top-down and imposed system with their associated targets and supervision to bottom up articulation of needs, pre-project engagement and involvement of the local communities as well as efforts to fully integrate local operation and management.

Conclusion

Modern scientific knowledge and the top-down development that has for long been espoused by multilateral development agencies promoting MSKS as the only solution to development problems, along with the culture they're embedded in, belie their claims for success, especially given the state of human civilization today. In most of the developing world, basic community needs remain unmet, especially in the rural areas and in the bulk of the urban centers which tend to be slums and informal settlements of village folk chased out of their villages and rural communities, either because of large state-sponsored and "critically needed" large scale development projects in natural resource extraction, large scale energy generation for attendant industries and the huge transportation and communications infrastructure projects needed to support them. What are considered essential and critical needs for survival and flourishing of communities, including clean air, safe and appropriate clothing and shelter, clean water, safe and healthy food, renewable energy, affordable and appropriate healthcare, education and critical information and communication technologies, remain a pipe dream for the vast majority of most developing country populations. Indeed, the inception of the AT movement, going back to the days of Gandhi, who we have argued was perhaps amongst the first "appropriate technologists" (Tharakan et al, 2005) was based on the recognition of the failures of traditional development paradigms.

The importance of IKS in this context becomes critical. As discussed, IKS can provide a tremendous intellectual, knowledge and technological resource base that is appropriate and sustainable and that will focus on addressing these needs in culture- and context-specific ways. IKS already have a head start in terms of sustainability and appropriateness. This recognition has lead to proposals for the establishment of Institutes for Indigenous Science and Technology (IIKS, 2012), and work on the fusion and integration of MSKS with IKS. Anamuah-Mensah and Asabere-Ameyaw (2004) have argued for the integration of IKS with the formal school curriculum, demonstrating the benefits that can accrue, with teachers engaged in curriculum development using existing community knowledge. MSKS and IKS should be brought closer together in interdisciplinary projects dealing with the links between culture, environment and development. It is important to articulate "informal" (IKS) and formal (MSKS) science as complementary, not contradictory. A heuristic that could provide a framework for this approach is suggested in Figure 1 below.

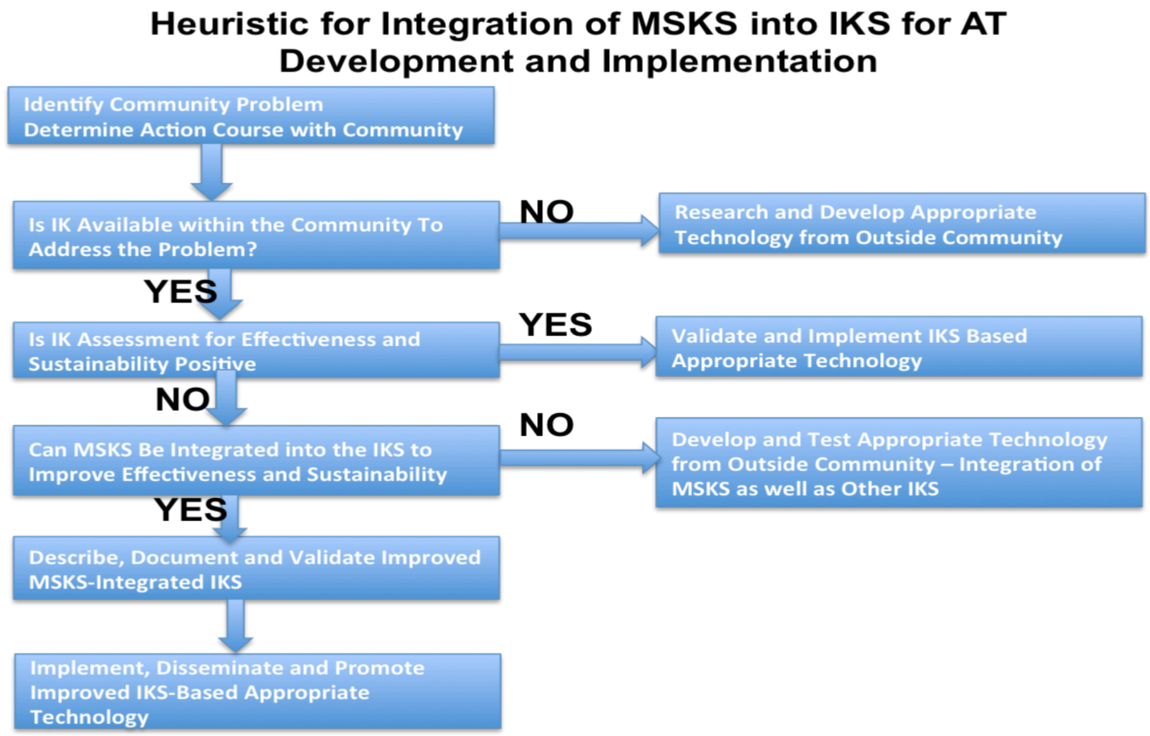

Figure 1 (Adapted from Aluma, 2004)

Finally, governments must commit to encourage effective dialogue between scientists, technologists and informal science practitioners. Curriculum developers, university lecturers, teacher trainers and teachers must commit to engage and accept this new vision, endeavoring to bring about an effective interface of the two knowledge systems. Engagement in this process of documentation, evaluation, assessment and adaptation of IKS with integration of MSKS, will substantially enhance capacity building and potential for successful AT development and deployment.

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The Potential of Critical Pedagogy for Broadening Software Engineering Ethics Education

Gada Kadoda, Ph.D.
Independent Researcher, Khartoum, Sudan
gadoda@gmail.com

Abstract

One of the main characteristics of "software" that sets it apart from other "engineered" objects is its intangibility, which presents difficulties, in specifying its needs, predicting overall behaviour or impact on users, and therefore, on examining the range of ethical questions that may be involved in a particular context. As a discipline, software engineering drew from older engineering disciplines for process and practice development, however its ethical issues interlink with Computer Science and the developments in Computer and Information Ethics as well as have become increasingly important in a world dominated by computers. The diversity of ethical issues in the field of software engineering prompted accreditation bodies to require contact hours of material related to social context and led programs to include critical thinking skills as part of students' technical training. This paper explores the potential of critical pedagogies in broadening software engineering ethics education by incorporating them in student outreach activities. The paper argues that their applied nature can link specific design decisions and ethical positions in "real-time" which can generate a "curiosity", in both student and teacher, to discover more of the "harm" or "good" that can result from the software solution and "change" in the process.

Keywords: Software Engineering Ethics, Computer and Information Ethics, Critical Pedagogy

Introduction:

The field of software engineering grew out of computer science in response to the "software crisis" of the 1960s that was characterised by the growth in complexity or criticality of computer applications and the specific problems of software projects going over budget and time. Work on defining processes and methods for "engineering" software in similar ways as material objects like buildings or cars built on pioneering work on programming such as (Dijkstra, 1968; Parnas, 1972), that laid out the foundations of development methodologies and early models such as Waterfall and Spiral. Still, borrowing from engineering and project management typical practices as requirements, design, construction, risk management, etc., did not produce the same preciseness of measurements found in traditional engineering work. This generated debates on whether software engineering is "genuine" engineering (Shaw, 1990, McConnell, 1999, Parr, 2013); as well as research on areas such as formal methods, software metrics and effort estimation, and calls for more rigorous and disciplined practices (Schmidt, 2013).

While the status of software engineering is still not conclusive, for example listed under computing by globally influential bodies like ABET, is not the focus of the paper. The origin of the field and its "transition" into an engineering discipline is relevant to the development of the field's professional obligations and ethical codes, as well as to the development of its curriculum. More specifically, the nature of software as an intangible object, which poses problems for specifying "non-functional" requirements and predicting its behaviour, also complicate ethical considerations because of the "logical malleability" of computers in how they make it possible for people to do a vast number of things that they were not able to do before (Moor, 1985). Since no one could do them before, many ethical questions never arose, and therefore no specific ethical rules or good practices were established to govern them. Moor called such situations "*policy vacuums*" and noted that some of them might generate "*conceptual muddles*". The fact that software engineering matured in computer science departments rather than in engineering schools, some researchers argue, led to an emphasis on moral or legal abuses committed with a computer in its approach to ethics. Ethics topics in software engineering textbooks discuss confidentiality, competence, intellectual property and computer misuse, and introduces the ACM/IEEE Software Engineering Code of Ethics that was developed in the early 1990s. However, ethical considerations in software engineering have been evolving over the past two decades from focus on customer and employer to look at societal implications of computer systems and different teaching approaches emphasising the need to equip students with a broad education necessary to understand the local and global impact of solutions on individuals, organisations and society. (ABET, 2014; ACM/IEEE-CS, 2014). Contemporary issues in general engineering ethics such as globalisation have raised questions for software engineers about computer crime, civil liberties, open access, digital divide, etc. Computer-related ethics is also becoming increasingly important for engineering ethics because of the dominance of computers in modern engineering practice.

This paper discusses some of the different approaches to ethics education and explores the potential of critical pedagogy in broadening software engineering ethics education by incorporating them in student outreach activities. The paper is structured to give an overview of developments in computer, information and software Engineering ethics in section 2, and teaching approaches in section 3. Section 4 presents a set of critical pedagogy practices and their application using two experiences at computer science departments, in the US and Sudan. The two experiences are supposed to be typical of teaching innovations meant to connect learning with context and therefore provided the setting where different ethical issues interplay where students themselves are the subject of the ethical issue. The final section concludes with emphasizing the relevance of these approaches to ethics education because of their potential to broaden as well as provide an applied component for teaching ethics.

Overview of Computer, Information and Software Engineering Ethics

Some of the early work on computer and information ethics is attributed to Norbert Wiener during World War II, who also founded the field of cybernetics and considered the social and ethical implications of electronic computers (Wiener, 1948). Wiener predicted that, after the War, the world would undergo "a second industrial revolution" — an "automatic age" with "enormous potential for good and for evil", that would create many new ethical challenges and opportunities. He explored some of the potential effects of information technology on key human values like life, health, happiness, abilities, knowledge, freedom, security, and opportunities, where he argued that societies "must provide a context where humans can realize their full potential as sophisticated information-processing agents, making decisions and choices, and thereby taking responsibility for their own lives". Walter Maner view that computer technology generated "wholly new ethics problems" (Maner 1996) was contested by Deborah Johnson and others who did not see computers do not generate ethically unique problems but merely "pose new versions of standard moral problems and moral dilemmas, exacerbating the old problems, and forcing us to apply ordinary moral norms in uncharted realms" (Johnson, 1997). She agreed with Maner that computer technology generate new specific ethics questions — for example, “Should ownership of software be protected by law?” or “Do huge databases of personal information threaten privacy?” Nevertheless, she maintained that such questions are simply “new species of old moral issues”, such as protection of human privacy or ownership of intellectual property, and not “wholly new ethics problems requiring additions to traditional ethical theories”. Moor provided another account of ethical issues in computing in his paper “What is Computer Ethics?” (Moor, 1985) where he discussed why computing technology raises so many ethical questions compared to other kinds of technology. One explanation was that computers are “logically malleable” A significant contribution to the ongoing “*uniqueness debate*”, reinforcing Maner's view, came in (Górniak-Kocikowska, 1996) claiming that “*computer ethics eventually will evolve into a global ethic applicable in every culture on earth*” and suitable for the Information Age and the global nature of the internet. In addition to the development of the software engineers’ ethical code, the 1990s also witnessed other important developments such as the information ethics theory of Luciano Floridi, the “*Flourishing Ethics*” (Floridi, 1999). Floridi argued that computer ethics should cover much more than “simply human beings, their actions, intentions and characters”. He offered his theory as another “*macroethics*” applicable to all ethical situations and complementary to traditional Western theories. His approach treats everything that exists as “*informational*” and therefore having the “*right to flourish*”. He calls the totality of informational entities “*the infosphere*”. If an entity in the infosphere suffers “*entropy*” or damage, the result is a partial “*impoverishment of the infosphere*”. On this interpretation of the world -- all that exists is “*informational*” with some moral worth, he argued that the focus of ethical attention shifts from “*evil*” or “*entropy*” to emphasis on “*preserving and enhancing the infosphere*”.

Beginning with the predictions and computer ethics work of Norbert Wiener and ending with Floridi’s “Flourishing ethics”, a common concern runs through computer ethics; namely, protecting and advancing central human values. Over the years, examples of problems that have attracted research and scholarship in computer ethics include: Computers in the Workplace; Computer Crime; Privacy and Anonymity; Intellectual Property; Professional Responsibility; Globalization; Social Implications of the Internet; Philosophical Foundations; and the Metaethics of Computer Ethics (Bynum, 2008). Many ongoing developments in engineering ethics education were influenced by developments in international standards such as the increased attention to the ethical responsibilities of engineers and the societal context of engineering. For instance, a minimum of three contact hours of material directly related to social context were introduced into the curriculum in the 1998 ACM IEEE Computer Science guidelines – known as EC2000 (ABET, 1998). The issue in this paper, as (Kreiner & Flores, 2004) put it “*is not whether ethics can be taught but more importantly what is the method that will best result in teaching the young what they need to know that ensures they will be ethical and act morally. That is the real issue.*”

Approaches in Software Engineering Ethics Education

The growing and dynamic role of software applications in different sectors inevitably places a significant burden on the software engineer because of the potential of doing, and enabling others to do, “harm” or “good”, as well as requiring “adaptable and relevant to new situations as they occur” professional codes. The ethical frameworks for teaching software engineering ethics have traditionally included engineering codes of ethics and the application of moral theories to examine ethical issues that arise within the professional interactions of the software engineer. An ethics course at Mälardalen University in Sweden was developed using Moor's concept of "Logical malleability" to examine the interactions and different contexts of the software engineer within and outside their immediate environment (Dodig-Crnkovic & Feldt, 2009). The course topics, intended for undergraduate students, included issues such as privacy and security, arising from computers data and communication capabilities, and extended the software engineer's concerns into rights-based ethical questions on power distribution, equal opportunities, equity, fairness, justice, gender and digital divide. Often courses include case studies, which are becoming popular in teaching engineering ethics (Harris, 2000). Cases come in different sizes and content, they can be long or short, real or fictional, technical or non-technical; they may be available in various forms, in print, online, multimedia, etc. Case methods have several common characteristics, according to Davis (1999) such as encouraging students to express ethical opinions, identify ethical issues and formulate and justify decisions; in addition to developing their' "sense of the practical context of ethics." A number of high profile cases such as Shuttle Challenger in 1986 are usually included along more of the typical ethical dilemmas encountered by most engineers. Several ethicists, most notably Pritchard (1998), have called for the development of more cases that focus on "good works". In the past decade, resources for software engineering ethics education have increased considerably and different curriculum models were developed that vary from required courses or by spreading ethics instruction throughout the engineering curriculum, to integrating ethics topics into Engineering, Technology and Society courses (Herkert, 2002).

There is pragmatism among many researchers about the unlikely prevalence of required ethics courses and call upon faculty to ensure ethical training is included and that "critical thinking skills are developed in the context of technical courses" (Ume & Chukwurah, 2012; Herkert, 2002). Different ideas on incorporating critical thinking skills in software engineering can be found in curriculum development efforts such as the "learner-centred education" which involves identifying critical skills that are associated with software development and searching for the relevant learning resources (Seffah, 2002). An experimental course developed by (Narayanan & Vallor, 2014) proposes five "*Ethically Constructive Habits of Mind and Action*" such as self-reflection and looking for role models, for linking the professional, and private, lives of the software engineer. Other researchers considered critical pedagogy as their teaching philosophy (Ibrahim, 2007), or as enabling tools for "*students to make the epistemic transformations*" to change rather than adapt and survive in the situation (Riley & Claris, 2009).

Exploring Critical Pedagogy in Student Outreach Activities

Critical pedagogy is based on Paulo Freire's ideas of education involving the struggle for equity and justice, and his experiences with Latin America peasants. In his classical book *Pedagogy of the Oppressed*, Freire connects the educational process to the broader socio-political context that he argues, would transform the classroom into an agent of social empowerment and action. (Freire, 1971) Acknowledging the need for students to rigorously prepare for the world as it is, Friere considered educators equally and ethically obligated to deliver the curriculum and at the same time raise critical questions about it. He argued that this approach would prepare students to struggle for the world as it could be, introducing them to a contradiction that challenges them epistemically and helps them "*understand what contradiction means, that human action can move in several directions at once, that something can contain itself and its opposite also*" (Shor & Freire, 1986), a contraction that makes one fall into "*hypocritical moralism*" (Friere, 1998). Some of the common practices from critical pedagogy used in academic programs, particularly social sciences, that involve topics on consciousness-raising, collaboration, coalition-building, social movements etc., (Hale, 2014), are explored in the following points using two experiences [3]at computer science departments, in the US and Sudan. The two experiences are supposed to be typical of teaching innovations meant to connect learning with context. The first is a curriculum development exercise, employing the concept of "socially relevant computing", at Rice and Sunny Buffalo Universities in the US, in collaboration with Microsoft; the second is a project at University of Khartoum and Sudan University of Science and Technology, based on UNICEF's "Technology for Development" concept.

a) *Generating the student as subject and knowledge producer*:

The course at Buffalo incorporated both problems of personal relevance to the 18-22 year olds e.g. weight management, and problems of relevance to the communities in which students live. It engages them in creating practical solutions (producing tools and devices). The experience of students in the Innovation Lab involved using open source software and basic mobile phones to provide real-time data collection and analysis capabilities for remote areas in the country. The specific constraints such as language, infrastructure, etc., required students to examine what they know, gaps in their knowledge, and learn in groups, to design solutions that fit the desired needs.

b) *Situating ourselves in the context*

Both examples involved students in site visits to gain an understanding of the context. For examples, the students from Buffalo worked closely with the stroke patient, and visited the Handicapped Children's Learning Centre, while the innovation lab teams visited the school kits warehouse and vaccination centre. The societal value of the projects brought a sense of moral obligation to follow best practices in software engineering processes, to develop systems that fit user needs and context, as well as knowledge of own privileges.

c) *Fusing teaching with consciousness raising*

The students at Buffalo and Rice invented things that apply outside of their circle of friends and fellow students, and the prospect of making a difference sustained and motivated them according to Buckley's account of the experience. "These projects have showed us that when students are passionate about the work they're doing, they will excel," says one of the capstone course instructors, who also observed that the students "recognize that long after they finish a project, real people are continuing to benefit from the technology." The concepts of Technology-for-Development allowed students to consider several issues in software engineering and their relationship to humanitarian development work.

d) *Building on each other's ideas and work in collaboration*

The socially relevant computing involved group work and students from different disciplines. Whereas communication devices were jointly developed by software engineering and electronics students, the hurricane evacuation project involved students from different engineering and social science fields. The innovation lab groups simulated software development teams and split along the phases of software development.

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[3] Analysis of US experience was based on literature review (Buckley, 2008; 2009), and on author's direct involvement with the Sudan project.

e) *Encouraging students to use their knowledge in everyday life*

The Sunny Buffalo experience involved developing course material on how mathematics can be used to interpret and better understand everyday events. Students explored programming topics through examples selected based on relevance and impact. Among topics were array using air pollution, sorting using mp3 jukebox. The innovation lab teams were encouraged to use their existing knowledge to learn (and teach each other) the new development tools.

Concluding Remarks

The concepts of "socially relevant computing" and "technology for development" embed globally shared values expressed in United Nations declarations into engineering practice and bring closer ideas of how engineers can intervene to "change the world", which many 18-22 aspire to. This is not to propose that the study of engineering becomes social or development studies, although the skill of the social scientist to go beneath the surface or the developmental worker to get close to the society's pressing needs, are both valuable. It is only to recognise that providing engineers with a broader education and critical minds is necessary for them to understand the societal value of what they do and the environmental and economic impacts of engineering designs and decisions, as well as contemporary ethical issues within and outside of the profession.

The tenet of critical teaching practice is that it "involves a dynamic and dialectical movement between doing and reflecting on doing" (Freire, 1998) which also requires a "personally meaningful and engaging experience" according to Dewey (Riley, 2009). The involvement of the student, directly, with the context and users in the engineering problem, can generate the movement between "doing and reflecting" and the conditions for exercising "critical thinking" skills. Primarily, the difference between critical pedagogy and case study approaches is that case studies cover a diverse set of ethical questions in which the students must imagine involvement, while the university experiences generate the student as the subject of an actual ethical issue. The early exposure to the questioning of engineering decisions in terms of the impact of their solutions, as the student is making them, can facilitate the understanding and internalisation of professional practice. For instance, the good practice of user involvement allowed Rice and Buffalo students develop a device that fits the stroke patient's need for more independence to do simple tasks like ordering a pizza.

However, have the team considered the sustainability of this independence in terms of device maintenance? Which contradictions are in play if users are dependent on external entities to sustain services? The innovation lab group explored the "good" their applications can bring such as reducing expense or eliminating physical effort on rural users, but would the application replace jobs in the community or isolate some like users who are non-literate or visually impaired. Does the responsibility of the engineer extend to consider disadvantaged users or settings to develop or recommend inclusive alternatives? Are they obliged to develop code that can be implemented on cheaper or open architecture devices? This paper does not propose that software engineers should consider *everything*, but that they should recognize their enormous potential to do harm or bring good.

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Ethics and Extinction: Micro versus Macro Appropriate Technology

*Verharen C.[1], Gutema, B.[2], Schwartzman, D.[3,] Tharakan J.[4], Bugarin F.[5], Fortunak J.[6], Kadoda, G.[7], Liu, M.,[8] Middendorf, G.[9]

[1]Department of Philosophy, Howard University, Washington, DC, 20059 USA
[2]Department of Philosophy, Addis Ababa University, Addis Ababa, Ethiopia
[3]Department of Biology (ret.), Howard University, Washington, DC 30059 USA
[4]Department of Chemical Engineering, Howard University, Washington, DC, 20059 USA
[5]Department of Sociology and Anthropology, Howard University, Washington, DC, 20059 USA
[6]Department of Chemistry and Pharmaceutical Sciences, Howard University, Washington, DC
[7]Independent Researcher, Khartoum, 13314 Sudan
[8]School of Social Work, Howard University, Washington, DC, 20059 USA
[9]Department of Biology, Howard University, Washington, DC, 20059 USA
*Corresponding Author: Phone 202 806 6811, Fax 202 806 3347, E-mail: cverharen@howard.edu

Abstract:

Ethical theory and technology practice raise two primary questions. First, what are the ethical principles driving sustainable appropriate technology? And second, what are the viable applications of those principles with respect to alternative appropriate technologies. The hypothesis of the study is that the earth is experiencing the current and sixth mass extinction. The methodology is first to review appropriate ethical principles to address this problem and then to examine their consequences in the field of renewable energy technologies. A primary engine driving mass extinction is current modes of energy production. Unless energy is readily and cheaply available, humans will struggle to form a single economic community that can guarantee the universal rights embodied in the United Nations Declarations of Universal Human Rights. Unfortunately, Micro-Appropriate Technology (AT) applications cannot presently replace the current carbon-based global energy system. The paper analyzes the ethical potential of Macro Photo-Voltaic and Concentrating Solar Power AT systems. The conclusion argues that the world's collective nations must undertake a global solar "Manhattan Project" both to arrest the sixth mass extinction and overcome the misery of billions in the Global South through ethical sustainable development.

Keywords: Ethics, Mass Extinction, Scarcity, Micro/Macro Appropriate Technology, Concentrating Solar Power, Sustainable Development

Introduction: Ethics and Extinction

Ethical theory and technology practice raise two primary questions. First, what are the ethical principles driving sustainable appropriate technology? And second, what are the viable applications of those principles with respect to alternative appropriate technologies. The hypothesis of the study is that the earth is experiencing the current and sixth mass extinction. The methodology is first to review appropriate ethical principles and then to examine their consequences in the field of renewable energy technologies.

Rather than calling our age the "Cenozoic," researchers like Soulé , Samways, Pauly, and Crutzen (Kolbert, 2014: 16) suggest using the "Catastrophozoic," "Homogenocene," "Myxocence" (from the Greek for *slime)*, and "Anthropocene." Estimates of the time to extinction of our species at present rates of CO_2 production range over a thousand years, perhaps due to ocean acidification through explosive methane release, sulfur bacteria and hydrogen sulphide poisoning, replicating the end Permian mass extinction. However, catastrophic weather events, population displacement through rising sea levels and other disruptive phenomena are projected in the short term future. Collapse of civilization is much more likely in this century if carbon emissions remain at their current level (Schwartzman, 2013). Demonstrably taking place in the present and future are the mass extinctions of non-human life forms.

Biophilia (Wilson, 1984) is insufficient to arrest the current and sixth mass extinction (Kolbert, 2014). Current global ethical systems furnish variable motives to move humans to take measures against extinction.

Applications of standard Eurasian and North American ethics to the rights of future generations are problematic for the following reasons. Utilitarianism is based on the assumption that we are required to act for the greatest good for the most number of people. The greatest good is taken to be satisfaction of desires or pleasure. Our ethical obligations to future human generations rest on our duty to maximize satisfaction. The ethicist Peter Singer (2011) among others expands the coverage of utilitarianism to organisms that have the capacity to feel pleasure and pain. However, organisms lacking that capacity have no moral status. Neither do the non-organic features of the planet, such as rivers, plains, mountains or oceans.

Kant claims that ethics must be based on the human capacity for generalization. Animals may have a capacity for generalization but it cannot match that of humans. Rawls follows Kant with an anthropocentric theory of justice based on human rationality (Rawls 1999). Therefore, only humans have moral standing. His position on prima facie obligations to future generations is the subject of debate (Matheny 2007).

Virtue ethicists like Aristotle claim that we should strive for excellence as a function of our nature and circumstances. Our greatest virtue is our capacity for abstract thinking. Full moral status is granted only to those with the greatest capacity for abstraction. The unborn lack that capacity (MacIntyre, 2007).

Traditional African ethics anticipate current radical movements like biocentrism and ecocentrism in their extension of moral standing to life forms other than human and even to the natural features of the planet (Gutema & Verharen, 2013). The collective approach to social responsibility, generally embedded in African ethics, agrees with critics of the traditional preoccupation of professional engineering ethics with individuals and their moral dilemmas. Such critics argue for the need to distinguish between "micro-level" analysis of 'individual technologies or practitioners' and "macro-level" analysis of 'technology as a whole' (Winner, 1990; Vandenburg, 1995). The pragmatism of African ethics is an attractive alternative to Euro-American ethical systems that have accompanied Global Climate Change (GCC), world-scale wars, weapons of mass destruction and the misery of billions in the Global South.

A science-informed pragmatic ethics finds reasons to act against extinction through reflection on the evolutionary process. The diversity of life and resulting ecosystem services are necessary conditions for the survival and flourishing of life itself on the planet—ours included (Daily et al. 1997). Wilson (2010), Pinker (2011) and Wrangham's (2004) research suggests that humans are *eusocial,* or willing to sacrifice self-interest for the sake of their larger groups—under the right circumstances.

Three factors have led to the increase of the human population from a handful some two hundred thousand years ago to over seven billion at present. First, other things being equal, a larger population has a better chance of survival. Second, the strength of a group's bonding principles augments its survival. Third, the excellence of every group member contributes to the group's survival. Augmentation of group size and strength depends on the capacity of individuals to place group interest before self-interest. These evolutionary constraints have driven the healthcare and agricultural revolutions that made the human population expansion possible.

However, conditions of scarcity militate against the exercise of human eusociality. Ervin Staub's (1989, 2013) documentation of the economic conditions that give rise to genocide, warfare and terrorism illustrates that a primary cause of human violence is scarcity, whether real or perceived. Some may argue that civilization does not suffer from the scarcity of energy, but rather from the well-known environmental and health impacts of the dominant supply, fossil fuels (85% of the 18 Terawatt global energy consumption) and its unequitable distribution arising from global economic practices.

While scarcity may be dissected into many dimensions, key aspects include technologies associated with food production, recycling and computing. In all of these, the current critical scarcity is energy. Unless energy is readily and cheaply available, humans will not be able to form a single economic community that can guarantee the universal rights embodied in the United Nations Declarations of Universal Human Rights. Rough estimates of the energy requirements for that community stand at 3.5 kilowatt/person. For 7 billion people, total required energy is 25 Terawatts (Schwartzman 2013).

Translating Ethical Theory into Appropriate Technology practice

The paper's first section addressed the ethical principles driving sustainable appropriate technology. The second section examines viable applications of those principles with respect to alternative appropriate technologies. Unfortunately, Micro-Appropriate Technology (AT) applications cannot presently replace the current carbon-based global energy system. It is questionable whether large-scale hydroelectric systems can count as "appropriate technology" because of their environmental and social impacts (Nüsser, 2013). Dependent on rain and snow patterns, they are at risk because of limited service life due to siltation and the effects of Global Climate Change (GCC).

Only highly efficient wind and solar technologies have the capacity to end energy poverty in the global South and provide the needed energy to sequester CO_2 from the atmosphere to bring the level down below the safe limit of 350 ppm. Macro wind-powered AT systems are hampered by inadequate battery or other energy-storage systems, as are photo-voltaic (PV) AT systems. However, Concentrating Solar Power (CSP) has advantages over other solar or wind installations. The primary advantage of CSP over other renewables is its capacity for energy storage (Global Energy Network Institute, 2006). CSP AT systems exhibit the potential to deliver sustainable energy sufficient to replace carbon-based fuels because of their capacity for dispatchable or baseload storage capacity.

Baseload is the backup supply of energy when a particular energy technology is not operating at full capacity. Commonly, supporters of continued reliance on fossil fuels and/or nuclear power raise the objection that wind/solar cannot meet the baseload challenge. But this claim is misleading. Currently available reliable and cheap storage technologies together with geothermal energy will facilitate the expansion of these renewables. For example, an offshore array of turbines may generate a baseload without the need for supplemental storage systems. The progressive expansion of a combined system of wind, photovoltaics, and concentrated solar power in deserts will generate a baseload simply because the wind is blowing and the sun is shining somewhere—provided the systems are linked in a single grid. In the short term, baseload may be backed up by fossil fuels, with coal being phased out first, followed by petroleum on the way to a completely wind/solar global energy infrastructure.

Macro Appropriate Technology

CSP is perhaps the most promising AT for contemporary replacement of fossil fuel technology. Three conditions are necessary to enable macro-CSP to accomplish this task. First the CSP units must be located in desert areas with high solar irradiation or Direct Normal Irradiance (DNI). Second, they must be linked into a global grid. Third, the linkage must be through High Voltage Direct Current (HVDC) transmission lines (SBC Energy Institute, 2013).

Cost is a factor in considering the viability of macro-CSP (Ibid.: 54-55). The International Energy Agency (Energy Technology Perspectives, 2012) estimates that the Levelized Cost of Energy of CSP would need to fall by more than 75% to arrest current climate-change scenarios. However, two factors make that a plausible scenario. First are the government-driven phase-in systems that Germany exhibits. Second are the economies of scale as CSP units spread through the world's desert areas. One of us visited the Abengoa Solar South Africa CSP plant being constructed just outside of Upington in the Northern Cape in South Africa in 2014. Importantly, this plant will be dry-cooled, reducing water consumption in the arid southern Kalahari Desert by one third.

Cost is not the only factor to be considered, however. Like other wind and solar projects, there are other considerations. CSP does not discharge greenhouse gases (GHGs) or other pollutants when in operation. Because of CSP's capacity for thermal storage, coal or petroleum back-up plants are unnecessary. Nevertheless, because of their scale, CSP plants require more materials for their construction than other wind and solar systems. However, CSP's required materials such as concrete, steel and glass offer excellent recycling potential

While CSP plants require minimal toxic substances, the heat transfer fluids used in parabolic troughs are flammable and can contaminate soils through leakage. Research is under way that may lead to uses of non-toxic substances such as water or molten salts.

CSP Limits

Several considerations are necessary to judge whether macro-CSP may qualify as a form of appropriate technology. First are environmental considerations. CSP space requirements run to 50 MW per km². Comparisons of CSP and PV area requirements are not yet accurate (Ong et al., 2013). Visual impact could be limited by reason of the fact that CSP plants are best suited to desert conditions.

Unfortunately, despite the best of intentions, it is likely that macro solar concentration projects will have large detrimental impacts on local ecosystems. They will, by their very nature, affect plant life that might otherwise grow in the "covered" area. Due to interception of sunlight, the panels would also affect animal life indirectly through changes and/or reduction in plant biomass, and indirectly via alterations in the availability of sun and shade to which the animals are adjusted and sometimes dependent on for thermoregulation. Further, changed light interceptions are likely to affect other aspects of the local microclimate by altering levels of humidity and other factors.

The counterargument on behalf of CSPs is based on the urgency for implementing renewable energy systems. If macro-AT is not implemented directly, then many of the life-forms in desert areas will be extinct due to GCC.

Second are political considerations. The Desertec Industries Initiative worked toward a network of Sahara desert-based CSP units with the potential to meet the energy needs of North Africa, Europe and parts of the Middle East. That initiative is faltering because of perceived threats of terrorism in North Africa. Lenz (2010) and the SBC Energy Institute (2013) advocate the installation of CSP units in other deserts with high insolation or DNI, such as the Kalahari, the Gobi, and the Great Australian desert. The risk of terrorism is currently believed to be lower in these locations.

Nonetheless, macro-CSP installations are invariably at risk from political unrest, whether national or international. That risk may be unavoidable unless PV technology becomes more susceptible to improved efficiency, scaling and cost reduction. The global 'Manhattan Project' scale energy systems with a global grid necessarily suffer the same deficits that Langdon Winner (1978) pointed out in macro nuclear power systems. Nuclear plants require massive capital infusion. As comparatively easy terrorist targets, they require complex defense systems, and governments must assume the costs of damaging nuclear power plant failures such as those in Chernobyl and Fukushima Daiichi. As the source of major capital and defense initiatives, governments assume the right to control the distribution of energy from macro-energy systems. Dissent from government policy can be controlled by limiting power distribution to dissident elements.

Micro-AT energy systems do not require the expense and risk of long-distance transmission lines. However, manufacture of those systems can still be controlled by government interests. We face a trade-off between the urgent need for Macro-AT energy systems to arrest GCC and the risks that such systems entail.

Third are equity considerations. The UNESCO report (2013) on 'Engineering Issues, Challenges and Opportunities for Development' recognizes a 'set of new ethical problems' that demand the development of 'global engineering ethics'. This 'global ethics', the authors of the report argue, is required to address concerns such as the modifications of nature, overconsumption, technology transfer, as well as questions concerning research and development priorities such as whether arresting climate change is more urgent than global poverty reduction.

Conclusion

The argument for the macro-CSP solution is that it can address both the needs of current and future generations in terms of the availability of energy resources. However, the different decisions about location of installations, procurement, funding, governance require the consideration of the dynamics of gender, 'race', ethnicity, class, geopolitics, and the like to anticipate the kinds of impact that CSP is likely to have on power relations at macro and micro levels.

A critical consideration is whether wind and PV systems with increased efficiency will be sufficient to dispense with CSP projects that are at risk to terrorism, political instability, and negative social or environmental impact. Unless there are marked advances in solar PV efficiency and economies of scale, the world's collective nations must undertake a global solar 'Manhattan Project'. This would be a necessary step both to avert GCC and to overcome the misery of billions in the Global South through ethical sustainable development.

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