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Education for ethical STEM: Scientific social responsibility and public policy

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ABSTRACT

This article reviews and reflects on the role of science, technology, engineering, and mathematics (STEM) by highlighting the importance of scientific social responsibility (SSR) and its implications to ethical education and public policy making. With special reference to artificial intelligence (AI) and biomedical technology, it argues that the development of a keen awareness and ethical standards has become a pressing need for research and educational institutions. Selected country cases are reviewed as examples to show the "state of the art" and indicate the complexity of major issues involved. The role of United Nations Educational, Scientific, and Cultural Organization (UNESCO) in promoting AI ethics is illuminated. Education for ethical STEM as well as public policy guidance are emphasized to foster SSR as a golden rule for any basic research and applied undertaking.

Key words: science, technology, engineering, and mathematics; artificial intelligence; biomedical education; ethics; scientific social responsibility, public policy

INTRODUCTION

The rapid advancement of science, technology, engineering, and mathematics (STEM) fields, particularly biomedical research and artificial intelligence (AI), has ushered in a new era of innovation and opportunity. On the other hand, the technological revolution is accompanied by a growing concern over the ethical implications of these developments.[1] As AI systems become increasingly sophisticated and integrated into our daily lives, for instance, a host of ethical dilemmas emerge, challenging our understanding of responsibility, security, privacy, and the very nature of humanity.[2] From autonomous weapons systems to algorithmic bias in hiring practices, the potential for abuse, misuse and unintended consequences is significant and nerve-wracking. The rapid pace of technological change outstrips our ability to fully anticipate and address these ethical challenges, creating a sense of urgency and uncertainty. In particular, the development of powerful AI tools raises questions about accountability, transparency, and the potential for job displacement worldwide. The recent corona virus disease 2019 (COVID-19) devastation also reminds us of the obligation for an overhaul of technological governance in the fields of biomedical technology (broadly defined).[3]

The development of STEM including biomedical technology and AI calls for more serious attention from social-philosophical researchers and public intellectuals who are or should be concerned with so-called scientific

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social responsibility (SSR) for scientists and technocrats alike. Ethical education appears to be the fundamental answer while public policy must also be made to ensure STEM development on the right path toward improvement of human well-being rather than the other way around. It is imperative that we engage in thoughtful and proactive discussions about the ethical implications of STEM including biotechnology, AI, and related enterprises. By fostering interdisciplinary collaboration between technologists, ethicists, policymakers, and the public, we can work toward a future where innovation is guided by principles of fairness, justice, and human well-being.

Our research question to guide this review article is: How to promote the development of STEM ethics education based on the principles of social responsibility and public policy? For the research purpose and core content of the paper, the ideas of ethical education and good governance in the STEM fields are important to both China and the rest of the World. However, we must first explain what we mean by ethical STEM along with an established terminology of ethical education *etc.*

ETHICAL EDUCATION AND ETHICAL STEM

Ethics is a branch of philosophy that deals with morality, or what is right and wrong, whereas morality is a system of beliefs and values that guide a person's behavior. Values are deep-seated beliefs about what is important in life, and principles are fundamental truths or rules that guide behavior. The term virtues are used to indicate positive character traits, such as honesty, courage, and wisdom.

"Ethical education", also popularly called moral education, refers to a form of teaching and learning that helps individuals develop a strong moral compass and the ability to make sound ethical judgments.[4] Conceptually different from a related term "educational ethics", ethical education involves teaching individuals about values, principles, and virtues, such as honesty, integrity, fairness, and compassion. The primary goals of ethical education are to:[5] (1) Develop moral reasoning skills: Equip individuals with the ability to think critically about ethical dilemmas and make informed decisions; (2) Cultivate empathy and compassion: Develop the ability to understand and share the feelings of others; (3) Foster ethical behavior: Encourage individuals to act in accordance with ethical principles and values; (4) Promote social responsibility: Inspire individuals to contribute positively to their communities and society as a whole.

There are various approaches to ethical education,[6] including: (1) Values clarification: Helping individuals identify and reflect on their own values; (2) Ethical dilemmas: Presenting real-world ethical dilemmas to encourage critical thinking and discussion; (3) Character education: Focusing on teaching specific virtues and character traits; (4) Moral development: Exploring the stages of moral development and how to progress to higher levels; (5) Service learning: Combining academic learning with community service to promote ethical action.

In education, there is a general belief that by integrating ethical education into formal and informal learning environments, individuals as students and lifelong learners can be empowered to make ethical choices and contribute to a more just and compassionate world.[7]

"Ethical STEM" refers to the responsible/ethical development and use of research results and innovations in STEM fields. It involves considering the potential impacts of technological advancements on society, the environment, and individual well-being. The importance of ethical STEM lies in ensuring that technology is developed and used for the betterment of humanity and avoids causing harm. Key ethical considerations in STEM include:[8] (1) Privacy and data security: Protecting personal information and ensuring responsible data collection and use; (2) Equity and fairness: Developing systems and algorithms that are free from bias and discrimination; (3) Accessibility and inclusivity: Making technology accessible to all, regardless of socioeconomic status or ability; (4) Environmental protection: Minimizing the negative environmental consequences of technological advancements; (5) Accountability and transparency: Ensuring that those who develop and deploy technology are held accountable for their actions.

By integrating ethical considerations into STEM education and research, the society can foster new generations of responsible innovators who are committed to using technology for good.[9] This will help to mitigate potential risks and ensure that technological advancements benefit society as a whole.

In the United States, the National Science Foundation (NSF) established a program called "Cultivating Cultures for Ethical STEM (CCE STEM)",[10] which funded research projects to identify (1) factors that are effective in the formation of ethical STEM researchers and (2) approaches to developing those factors in all the fields of science and engineering that NSF supports. In 2018, CCE STEM solicited research proposals that explore the following: What constitutes responsible conduct for research (RCR), and which cultural and institutional contexts promote ethical STEM research and practice and why? As NSF suggests (ibid.), topics to consider may include: honor codes, professional ethics codes and

licensing requirements, an ethic of service and/or service learning, life-long learning requirements, curricula or memberships in organizations (*e.g.* Engineers without Borders) that stress RCR, institutions that serve underrepresented groups, institutions where academic and research integrity are cultivated at multiple levels, institutions that cultivate ethics across the curriculum, or programs that either promote group work or do not grade. Particularly, NSF is interested in such research questions as: Do certain labs have a "culture of academic integrity"? What practices contribute to the establishment and maintenance of ethical cultures and how can these practices be transferred, extended to, and integrated into other research and learning settings? "Successful proposals typically have a comparative dimension, either between or within institutional settings that differ along these or among other factors, and they specify plans for developing interventions that promote the effectiveness of identified factors"(ibid.). NSF further stipulates that CCE STEM research projects will use basic research to produce knowledge about what constitutes or promotes responsible or irresponsible conduct of research, and how to best instill students with this knowledge. In some cases, projects will include the development of interventions to ensure responsible research conduct. Proposals including international collaborations are encouraged when those efforts enhance the merit of the proposed work by incorporating unique resources, expertise, facilities or sites of international partners (ibid.). In 2024, the US NSF issued a new call for proposals (CFP) under a renewed/updated Ethical and Responsible Research (ER2) program.[11]

In the following, we will review a few more key themes by introducing some other country cases (*e.g.*, India and China) as well as their implications to the international cause of "scientific social responsibility" for the sake of human well-being, social justice, and world peace.

FROM CORPORATE SOCIAL RESPONSIBILITY (CSR) TO SSR

CSR as a management concept has long been used by business organizations (companies) to give back to society while bolstering brand reputation.[12] Its history may be traced back over two centuries, with the birth of "responsible organizations" in the 1800s.[13] As a modern practice it emerged in the 20th century, with the term "corporate social responsibility" coined in 1953 by American economist Howard Bowen who is often referred to as the father of CSR.[14] In 1971, the concept of a "social contract" between businesses and society was introduced under the idea of CSR, acknowledging officially that companies exist and function because of public consent and, therefore, there is an obligation to contribute to the needs of society. As more and more companies began incorporating social interests in their business practices while becoming more responsive to stakeholders, the 1990s marked the beginning of a widespread approval or universal acceptance of CSR. By the early 2000s, it had become an essential development strategy for various types of organizations.[15]

SSR can be defined as the confluence of scientific knowledge with visionary leadership and social conscience, concerned with building synergies among all stakeholders in the scientific research community. The term SSR is analogous to CSR and appeared in modern literature even earlier.[12] Samanth *et al.*[15] conducted a systematic literature review of SSR from year 1947 to 2019 from various fields in order to evaluate SSR. Their findings show that there has been a dramatic increase of scholarly interests in SSR since the 1990s, which is similar to the case of CSR, with attention also from political leaders.[12] However, compared to CSR, the contribution and influence of SSR are regarded minimally thus far. SSR has not been well practiced but remains relatively unknown to the research community and the society at large. Efforts have to be made to change the situation. Angewandte Chemie International Edition of the German Chemical Society, one of the prime chemistry journals in the world, published in 2011 an editorial entitled "Scientific Social Responsibility: A Call to Arms".[16] In their call for a "preemptive strike", the authors urge that scientists develop a new mindset and regain the trust of society by reinvigorating SSR and actively voicing their commitment to it. While CSR may provide some inspiration, they argue, the scientific world is faced with the urgent challenge to design and develop academic leadership as a separate discipline with an emphasis on responsible use of research funds.[12]

Broadly speaking, responsible scientific action entails consideration of public welfare and population health at every step, including making the choice of what to study, for what purpose, and how to carry it out in a way that is sanctioned by public policy for the sake of individual and societal well-being. This has become even more apparent since the outbreak of the COVID-19 pandemic, accompanied by other crises such as deadly nuclear and cyber threats. Here, with particular attention to biomedical technology, the development of a keen awareness and ethical standards is seen as a pressing need for social policy to promote SSR for research and educational institutions worldwide (ibid.).

In terms of country cases, India has been a leader in the movement toward SSR, as one of the first nations in the world to implement such a national policy on the lines of CSR (ibid.). In 2019, a draft of the new SSR Policy was published by the Department of Science and Technology (DST) of Indian Government, building

upon its tradition of earlier policies (*e.g.*, Scientific Policy Resolution 1958, Technology Policy Statement 1983, S & T Policy 2003, Sci-Tech and Innovation Policy 2013). The SSR policy was formally released on India's National Technology Day 2022 with a set of guidelines in order to "create an ecosystem with a two-way engagement between science and society".[17] This national experiment deserves international attention, particularly to the research studies delving further into and quantifying the results of the experiment over the past few years.

With an interest in biomedical education and health promotion, a look into another giant case of China is also helpful with reflection on continuing development of SSR in specific institutional and cultural contexts.[12]

BIOMEDICAL EDUCATION, HEALTH ETHICS, AND IDEOLOGICAL-POLITICAL EDUCATION IN STEM

Biomedical research plays a pivotal role in the advancement of science in the 21st century. Life scientists as educators also share their commitment to SSR by contributing to health promotion, particularly in the biomedical field. From an international perspective, such positive contribution may result from related instructional arrangements by higher education institutions. And researchers from various countries have attempted to validate the effectiveness of the education with some empirical evidence.[12]

In terms of the potential impact of biomedical/health science education on change of health behavior, Muñoz-Rodríguez *et al.*[18] conducted a survey to explore the influence of an enrolled degree course on health and eating habits in a population of Spanish university students. Their findings show that the self-reported body mass index (BMI) was higher for the non-biomedical students group, which also reported less regularity in taking meals, eating fewer colored vegetables and fruits, and a higher alcohol intake. In contrast, the proportion of students that showed more interest in the diet-health duality and a desire to adopt healthier habits was larger in the biomedical students' group than in the non-biomedical group. The dietary habits discovered in the study suggest that biomedical students make healthier food choices; additionally, the group of biomedical students took more walks per week (ibid.). Research like this shows that biomedical education, in addition to its scientific purposes, does affect the health behavior of the students with a positive impact on health promotion.[12]

Aside from the potential benefits demonstrated by the kind of research mentioned above, the term "scientific social responsibility" carries strong moral implications for scientists and science educators. In the biomedical field as well as allied health professions, it is the subject of scientific and health ethics that both researchers and practitioners are exposed and obliged to.[19] There are certain ethical rules and principles, including non-maleficence, beneficence, respect for individual autonomy, confidentiality, and justice that appear consistently. Some of the ethical issues may arise in clinical practice anywhere, including informed consent, non-initiation and termination of medical therapy, genetic intervention, and allocation of scarce health resources. However, what can be considered moral and ethical should be further examined within particular, diverse national contexts.[12]

In current China, for example, beyond the usual discussion of scientific and health ethics there is an additional layer that must be considered. That consideration or educational requirement is called *Si Zheng* in Chinese (in abbreviated form), which means ideological and political education. Aside from courses specifically designed for that purpose, it requires or encourages teaching all other courses from official ideological and political perspectives, or explaining course contents (including all STEM curricula) as much as possible on the ideological and political dimension. Therefore, it's also called "ideological education in the curriculum", or "curriculum ideology and politics".[20] The undertaking, which has seen a dramatic rise over the past few years, possesses strong connections to the established Chinese practice of *De Yu* (moral education) within its educational systems ever since the People's Republic was founded. Its evolution to attain such a dominating status with the current "state of art" of *Si Zheng* is worth studying as a renewed case "with Chinese characteristics/style, " which attempts to break new ground for a unique "Chinese model/road" to modernization. While it may sound like something beyond the subject of this article, it is of great relevance to the discussion of SSR in the particular cultural and historical contexts in which we can sense the complexity of the issues involved.[12]

The case of China implicates more and more geopolitical considerations in recent years compared to the post-Mao open-door and reform era, which may also be reviewed in another "rational" way (a public policy analysis model) in terms of its general public policy (GPP) pattern identified as a changing "post-economic state".[21] The theory suggests that the emphasis, focus, or center of the nation's public policy system has shifted from extreme politicalization (*e.g.*, "Cultural Revolution") to an outright "economic state" (*e.g.*, in the post-Mao reform and open-door era), and to a supposedly more balanced development strategy now. The "de-economicization" of the GPP, however, may also lead to re-politicalization which bears heavily on the trend of *Si Zheng* discussed in

the above.

In a broader international view, the role of public policy regarding ethical issues and SSR in STEM fields can be discussed in terms of the common and significant role of a science and technology policy.

AI ETHICS AND THE UNITED NATIONS

The United Nations Educational, Scientific and Cultural Organization (UNESCO) has pointed out a worldwide need for AI ethics, that is, "Getting AI governance right is one of the most consequential challenges of our time, calling for mutual learning based on the lessons and good practices emerging from the different jurisdictions around the world" (https://www.unesco.org/en/artificial-intelligence/recommendation-ethics#, retrieved December 13, 2024). According to UNESCO, AI plays a greater and greater role in billions of people's lives nowadays. These general-purpose technologies are reshaping the way people work, live, and interact. The rapid rise of AI tools, such as ChatGPT and DeepSeek most recently, has created abundant opportunities, from facilitating healthcare diagnoses to enabling human connections through social media and increasing labor efficiencies through automated tasks. However, these rapid changes also raise profound ethical concerns, arising from potentially embedded biases and various other threats posted by AI systems. As UNESCO stresses, in no other field is the ethical compass more relevant than in AI. Without the ethical guardrails, AI risks reproducing real world biases and discrimination, fueling divisions and threatening fundamental human rights and freedoms. Unfortunately, such risks associated with AI have already begun to compound on top of existing inequalities, resulting in further harm to already marginalized populations (ibid.).

As the leading advocate for AI ethics, UNESCO has established a Global AI Ethics and Governance Observatory, along with such major platforms as the Global Forum on the Ethics of AI 2024-Changing the Landscape of AI Governance. The aim of the UNESCO Global AI Ethics and Governance Observatory is to provide a global resource for policymakers, regulators, academics, the private sector and civil society to find solutions to the most pressing challenges posed by AI. It showcases information about the readiness of countries to adopt AI ethically and responsibly. UNESCO also hosts the AI Ethics and Governance Lab, which gathers contributions, impactful research, toolkits and good practices (ibid.).

As a major result of these efforts, UNESCO produced the first-ever global standard on AI ethics in November 2021 - the Recommendation on the Ethics of Artificial Intelligence, applicable to all 194 member states.[22] Central to the Recommendation are four core values which lay the foundations for AI systems that work for the good of humanity, individuals, societies and the environment: (1) Human rights and human dignity: Respect, protection and promotion of human rights and fundamental freedoms and human dignity; (2) Living in peaceful, just, and interconnected societies; (3) Ensuring diversity and inclusiveness; and (4) Environment and ecosystem flourishing (ibid.). UNESCO views the protection of human rights and dignity as the cornerstone of the Recommendation, based on the advancement of fundamental principles such as transparency and fairness, always remembering the importance of human oversight of AI systems. Yet, what makes the Recommendation exceptionally applicable are its extensive Policy Action Areas, which allow policy-makers to translate the core values and principles into action with respect to data governance, environment and ecosystems, gender, education and research, and health and social wellbeing, among many other spheres. With a dynamic understanding of AI, UNESCO provides ten core principles that lay out a human-rights centered approach to the Ethics of AI (ibid.).

While values and principles are crucial to establishing a basis for any ethical AI framework, recent movements in AI ethics have emphasized the need to move beyond high-level principles and toward practical strategies. In terms of actionable policies, the UNESCO Recommendation sets out key areas for policy actions including (ibid.): (1) Economy and Labor ("Member States should consider and attempt to regulate the impact of AI systems on the labor market. AI-related studies should be made a core skill at all educational levels to help close the skill gap. It will boost market competition and ensure consumer protection on a national and international scale"); (2) Data Policy ("Member States should implement mechanisms for effective data governance strategies to ensure individual privacy while ensuring adequate data collection and means to regulate its use"); (3) Ethical Governance and Stewardship ("AI governance mechanisms should be inclusive, transparent, multidisciplinary, multilateral and multi-stakeholder. In other words, communities impacted by AI must be actively in-volved in its governance in addition to experts across a range of disciplines. Additionally, governance must extend beyond mere recommendations to include anticipation, enforcement and redress"); (4) Education and Research ("Member States should provide adequate AI literacy education to the public, including awareness programs on data. In doing so, the participation of marginalized groups should be prioritized. Member States should also encourage research initiatives on ethical AI"); (5) Health and Social Wellbeing ("Member States should aim to

deploy AI to improve health and tackle global health risks. AI in healthcare and mental healthcare should be regulated to be safe, effective, efficient and medically proven. Additionally, Member States should encourage research into the impact of AI on mental health and wellbeing"); (6) Gender ("Member States should maximize the potential AI has to contribute to gender equality while preventing any potential for AI to exacerbate gender gaps. There should be dedicated funds for policies which support women and girls to make sure they are not left out. For example, investment for women in STEM careers"); (7) Environment and Ecosystems ("Member States and businesses should assess direct and indirect environmental impacts of AI systems, including their carbon footprint, energy consumption and raw material extraction. Where necessary, Member States should also introduce incentives to ensure AI solutions are used to support the prediction, prevention, control and mitigation of climate-related problems"); and (8) Ethical Impact Assessment (EIA, a structured process which operationalizes the Recommendation by helping AI project teams, in collaboration with the affected communities, to identify and assess the impacts an AI system may have) (ibid.).

ETHICAL EDUCATION FOR STEM ADVANCEMENT

Ethical education for STEM development is increasingly important.[23] It's not merely a luxury, but an imperative to safeguard human values and societal well-being in the age of intelligent machines. At the heart of ethical STEM development lies the recognition that technology is not neutral. For example, algorithms are trained on data, and the biases present in that data can be amplified and perpetuated by AI systems. This can lead to discriminatory outcomes in areas such as hiring, lending, and criminal justice. Ethical education equips AI developers with the critical thinking skills to identify and mitigate these biases, ensuring that AI systems are fair and equitable.[24]

Moreover, ethical education fosters a sense of accountability among AI developers. As AI systems become increasingly complex and autonomous, the potential for unintended consequences grows. Ethical education emphasizes the importance of transparency and explainability, enabling developers to understand how their algorithms function and to anticipate potential risks. This transparency is crucial for building public trust in AI and for ensuring that AI systems are subject to human oversight and control. Ethical education also plays a pivotal role in addressing the broader societal implications of AI. As AI systems become more sophisticated, they raise questions about issues such as job displacement, privacy, and the erosion of human autonomy. Ethical education encourages AI developers to consider the long-term consequences of their work and to engage in open dialogue with policymakers, ethicists, and the public to shape the future of AI in a responsible manner. All in all, ethical education is becoming an indispensable component of AI development. By fostering critical thinking, accountability, and a sense of social responsibility, it empowers AI developers to create technology that benefits humanity rather than harming it. As AI continues to evolve, ethical education will remain essential to ensuring that this powerful technology is used for good (ibid.).

Generally speaking, the RCR is widely acknowledged as an essential component of professional education, particularly in the STEM disciplines.[25] Institutional mechanisms are established to ensure RCR in many countries around the world. Institutional review boards (IRBs) or research ethics committees, for example, provide a core protection for human research participants through advance and periodic independent review of the ethical acceptability of proposals for human research. Animal welfare is also often a part of the RCR oversight. IRBs were codified in US regulation over three decades ago and are widely required by law or regulation in jurisdictions globally. This has greatly helped to achieve ethical STEM on the national and global scales.

Since the inception of IRBs, the research landscape has grown and evolved, as has the system of IRB review and oversight. In the United States, evidence of inconsistencies in IRB review and in application of federal regulations has fueled dissatisfaction with the IRB system. Some complain that IRB review is time-consuming and burdensome without clear evidence of effectiveness at protecting human subjects. Multiple proposals have been offered to reform or update the current IRB system, and many alternative models are currently being tried. It would be interesting for future research to provide examples of these proposals and how they may be too flawed to adopt, and also to report on the progress of the trials of these alternative models and explain what these models are.

Current focus on centralizing and sharing reviews requires more attention and evidence. Proposed changes to the US federal regulations may bring more changes. Data and resourcefulness are needed to further develop and test review and oversight models that provide adequate and respectful protections of participant rights and welfare and that are appropriate, efficient, and adaptable for current and future research.[26]

ETHICAL STEM AND PUBLIC POLICY

From AI to biotechnology, the advancement of STEM has revolutionized countless aspects of human life. These innovations hold immense potential to address global challenges and improve quality of life. On the other hand, the rapid pace of technological progress has brought up profound ethical questions and concerns. As a result, the development of sound public policy that governs the ethical use of STEM is imperative.[27]

Ethical STEM, a framework that we use to integrate ethical considerations into scientific research and technological development, is crucial in shaping a future where innovation is aligned with human values. By prioritizing ethical principles such as fairness, transparency, and accountability, we can help to ensure a right path for technological advancements. And public policy plays a pivotal role in operationalizing these principles.

One critical area where public policy intersects with ethical STEM is in the regulation of emerging technologies. As AI becomes increasingly sophisticated, policymakers must grapple with issues such as algorithmic bias, job displacement, and the potential for autonomous systems to make life-or-death decisions. By enacting regulations that promote transparency, accountability, and human oversight, policymakers can mitigate the risks associated with AI and ensure its responsible development. Another important area of focus is data privacy and security. As vast amounts of personal data are collected, analyzed, and used, it is essential to protect individuals' privacy rights and safeguard sensitive information. Public policy can help to establish robust data protection frameworks that balance the need for innovation with the imperative to protect individual privacy. Furthermore, public policy can play a role in promoting ethical STEM education. By integrating ethics into STEM curricula, we can equip future generations with the knowledge and skills to navigate the ethical complexities of technological advancement. This will foster a culture of responsible innovation and encourage the development of technologies that serve the public good. In an interdisciplinary perspective, ethical STEM and public policy are inextricably linked. By working together, scientists, engineers, policymakers, and the public can shape a future where technological innovation is guided by ethical principles. By prioritizing fairness, transparency, and accountability, we can harness the power of STEM to address global challenges and create a more just and equitable world (ibid.).

Science and technology policy is a subfield of public policy concerned with the development and implementation of guidelines and regulations that shape the direction and impact of scientific research and technological innovation.[28] These policies influence a wide range of areas, including: (1) Infrastructure: Governments invest in research facilities, laboratories, and other infrastructure necessary for scientific advancement; (2) Education and workforce development: Policies aim to develop a skilled workforce in STEM fields; (3) Research funding: Governments allocate significant funds to support scientific research, often through grants and contracts; (4) Ethical guidelines: Governments address the ethical implications of emerging technologies, such as AI and biotechnology; (5) Intellectual property: Policies related to patents, copyrights, and trademarks protect intellectual property rights; (6) International cooperation: Governments collaborate with other countries on scientific research and technology development.

It's important to remember that science and technology policy faces various charges and challenges, including (ibid.): (1) Public understanding of science: Promoting public understanding of science and fostering informed decision-making; (2) Balancing short-term and long-term goals: Striking a balance between immediate needs and long-term investments in research; (3) Global competition: Competing with other countries to attract top talent and secure technological leadership; (4) Ethical considerations: Addressing the ethical implications of emerging technologies and ensuring their responsible development.

Despite the challenges, science and technology policy offers immense opportunities to address global issues such as disease/epidemic, poverty, and climate change. By investing in research and innovation under well intended science and technology policies, governments can drive economic growth, improve quality of life, and strengthen national security. All these point to the essential principles of ethical STEM highlighted in this article.

Nation states are putting more and more emphases on science, technology and innovation policies.[29] Besides government agencies, major actors/players (a term mostly used in a political model of policy analysis) in science and technology policy include academic institutions such as universities and research institutions, which conduct fundamental research and train future scientists and engineers, and industry or private sector companies, which invest in research and development (often in collaboration with academia and government agencies). To provide national governments with some guidance, the United Nations Conference on Trade and Development (UNCTAD) published a set of guidelines in terms of A Framework for Science, Technology and Innovation Policy Reviews.[30]

Domestic and international non-governmental/non-profit organizations, including UNESCO, World Health Organization (WHO), World Trade Organization (WTO), *etc*., play significant roles in global governance with science and technology policy guidelines or advocacy. They promote specific policy goals for consideration/adoption by the governments of nation states, including public health, environmental protection, arms control, *etc*. Especially, UNESCO has led the international effort to ensure that science and technology develop with strong ethical guardrails for decades. Be it on genetic, AI, or other STEM research, UNESCO has delivered global standards to maximize the benefits of the scientific discoveries, while minimizing the downside risks, ensuring they contribute to a more inclusive, sustainable, and peaceful world. It has also identified frontier challenges in areas such as the ethics of AI, neurotechnology, climate engineering, the Internet of things, and other fields.[31] These efforts show great promise for shared SSR and ethical STEM across the international community.

CONCLUSION

The main issue addressed in this article is the role of STEM education and research in promoting individual and societal well-being. The major argument is that STEM research and education contains a social dimension in terms of its implications to public welfare and population health. With particular attention to AI, the development of a keen awareness and ethical standards has become a pressing need for public policy to promote SSR for scientific research and educational institutions. An international perspective on ethical issues in STEM education and practice including AI is more important than ever to achieve a higher-level understanding. Cultural sensitivity is equally instrumental to the inquiry,[32] particularly in relation to China's recent ideological and political contexts showing the complexity of the issues involved. By combining an interest in the social dimensions of STEM with a conceptual framework of SSR, our understanding of how physics, chemistry, biology, behavior, psychology, society, and environment interact will be improved.[33] There are many "uninhabited zones" in such looming fields as AI.[34] It is important to understand how education and public policy may ensure ethical STEM including health ethics and AI ethics to help advance the causes of public welfare from an interdisciplinary perspective. A systems approach can inform our understanding of the underlying causes of the ethical issues across generations and populations. And ethical education research can help us identify potential barriers to the achievement of SSR as the gold standard of true excellence.[35]

DECLARATION

Some of the original ideas were first expressed via an open-access online outlet (Chen & Qin, 2022), which are adapted and expanded for the needs of advancing ethical STEM education worldwide.

Author contributions

Chen SY: Conceptualization, Logical Reasoning, Structure, Writing-Original draft preparation. Chen A: Writing- Draft revision/editing. Gu J: Writing - Literature, proofing. Xu JS: Industrial Consultation, and Writing - Research questions, practical perspectives, draft reviewing. Chen XJ: Coordination, and Writing-STEM Contents, approval of the final manuscript.

Use of Large Language Models, AI and Machine Learning Tools

AI assistance is utilized in certain literature search and review efforts.

Ethics approval

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REFERENCES

1. Expert Panel of Forbes Technology Council. 16 current and potential ethical crises in technology. Forbes, Accessed December 23, 2024. https://www.forbes.com/councils/forbestechcouncil/2023/07/25/16-current-and-potential-ethical-crises-in-technology/
2. Pazzanese C. Great promise but potential for peril: Ethical concerns mount as AI takes bigger decision-making role in more industries. The Harvard Gazette, Accessed December 23, 2024. https://news.harvard.edu/gazette/story/2020/10/ethical-concerns-mount-as-ai-takes-bigger-decision-making-role/
3. Xafis V, Schaefer GO, Labude MK, Zhu YJ, Hsu LY. The perfect moral storm: Diverse ethical considerations in the COVID-19 pandemic. *Asian Bioeth Rev*. 2020;12(2):65-83.
4. Gill, Scherto, & Thomson, Garrett (eds.). *Ethical Education: Towards an Ecology of Human Development*. Cambridge University Press; 2020.
5. Avci, E. A normative analysis to determine the goals of ethics education through utilizing three approaches: rational moral education, ethical acculturation, and learning throughout life. *Int J Ethics Educ* 2. 2017;(2):125-145.
6. Susan L. *Approaches to Ethics in Higher Education: Teaching Ethics across the Curriculum*. University of Leeds.
7. Ashby-King DT, Boyd K. Integrative ethical education: An exploratory

investigation into a relationally based approach to ethics education. *J Commun Pedagog*. 2020(3):65–81.
8. Tekerek M, Karakaya F, Tekerek B. Ethical Reasoning in STEM Disciplines. *J Educ Pract*. 2016;(7):182-188.
9. Joyce, KA, Darfler, K, George, D, Ludwig, J, Unsworth, K. Engaging STEM Ethics Education. *Engag Sci Technol Soc*. 2018(4):1-7.
10. NSF. Cultivating Cultures for Ethical STEM (CCE STEM). The U.S. National Science Foundation. Accessed December 27, 2024. https://new.nsf.gov/funding/opportunities/cce-stem-cultivating-cultures-ethical-stem/505027/nsf18-532
11. NSF. Ethical and Responsible Research (ER2). The U.S. National Science Foundation. Accessed December 27, 2024. https://new.nsf.gov/funding/opportunities/er2-ethical-responsible-research
12. Chen SY, Qin YX. On Ethics, Biomedical Education and Health Promotion: International and Chinese Perspectives. *Int Healthc Rev*.
13. Staff Writer. *A Brief History of Corporate Social Responsibility (CSR)*. Thomas Publishing Co. Accessed Sep 25, 2022. https://www.thomasnet.com/insights/history-of-corporate-social-responsibility/
14. Bowen, HR. *Social Responsibility of the Businessman*. New York: Harper & Row.
15. Samanth MV, Hemchand J, Vrushank AK, Swamy DR. Scientific social responsibility - A systematic literature review. *Int J Adv Res Ideas Innov Technol*, 2021;7(2):V7I2-1335.
16. Krogsgaard-Larsen P, Thostrup P, Besenbacher F. Scientific Social Responsibility: A Call to Arms. *Angew Chem Int Ed*. 2011;46(50):10738-10740.
17. Dept. of Science & Technology. *Scientific Social Responsibility (SSR) Guidelines*. New Delhi: Government of India; 2022
18. Muñoz-Rodríguez JR, Luna-Castro J, Ballesteros-Yáñez I, Pérez-Ortiz JM, Gómez-Romero FJ, Redondo-Calvo FJ, *et al*. Influence of biomedical education on health and eating habits of university students in Spain. *Nutrition*. 2021;86:111181.
19. Vevaina JR, Nora LM, Bone RC. Issues in biomedical ethics. *Dis Mon*. 1993;39(12):869-925. PMID: 8243220.
20. Liang W. [On the English translation of "Kecheng Si Zheng".] Accessed Oct. 1, 2022. https://www.weibo.com/ttarticle/p/show?id=2309404784907892425180
21. Chen, S. Policy system, general public policy (GPP), and comparative social policy: A tale of the economic state *vs*. welfare state (and more). In: Chen SY ,ed. *Social Work, Mental Health, and Public Policy in Diverse Contexts*. New York & Global: Springer Nature; 2023: 13-21
22. UNESCO. *UNESCO's Recommendation on the Ethics of Artificial Intelligence*. UNESCO; 2023
23. Kreth Q, Schiff DS, Lee J, Borenstein J, Zegura E. Social Responsibility and Ethics in STEM Education: The State of the Field. In: Hildt E, Laas K, Brey EM, Miller CZ, eds. *Building Inclusive Ethical Cultures in STEM*. The International Library of Ethics, Law and Technology, Springer, Cham; 2024: 19-33.
24. Mirea N, Palade M, Gaureanu A. STEM Education, Artificial Intelligence, and Ethical Challenges. In: *Artificial Intelligence for Human-Technologies- Economy Sustainable Development*. MakeLearn, TIIM & PIConf; 2024.
25. Briggle A, Holbrook JB, Oppong J; Hoffmann J; Larsen EK, Pluscht P. Research Ethics Education in the STEM Disciplines: The Promises and Challenges of a Gaming Approach. *Sci Eng Ethics*. 2016;(22):237-250.
26. Grady C. Institutional Review Boards: Purpose and Challenges (2015). *Chest*. 2015;148(5):1148–55.
27. Herkert, JR. Engineering Ethics and Public Policy. In: *Social, Ethical, and Policy Implications of Engineering: Selected Readings*, IEEE; 2000: 145-146.
28. Stine, DD. *Science and Technology Policymaking: A Primer*. Congressional Research Service; 2009.
29. Lundvall, Bengt-Åke, and Borrás, Susana (2005). Science, Technology and Innovation Policy. In: Fagerberg J, Mowery DC, Nelson RR, eds. *The Oxford Handbook of Innovation*. Oxford University Press; 2005: 599-631.
30. United Nations Conference on Trade and Development (UNCTAD). *A Framework for Science, Technology and Innovation Policy Reviews*. UNCTAD; 2019.
31. UNESCO. Ethics of Artificial Intelligence: The Recommendation. The United Nations Educational, Scientific and Cultural Organization. Accessed December 27, 2024. https://www.unesco.org/en/artificial-intelligence/recommendation-ethics
32. Mcnulty JK, Fincham FD. Beyond positive psychology? Toward a contextual view of psychological processes and well-being. *Am Psychol*; 2012;67(2):101-110.
33. Braveman P, Gottlieb L. The social determinants of health: It's time to consider the causes of the causes. *Public Health Rep*. 2014;129(Suppl 2):19-31.
34. Zhang, B. Venturing into the "uninhabited zone" to explore the path of artificial intelligence. *Engin Educ Rev*. 2024;2(2):45-65.
35. Butts, CF. Science and Social Responsibility. *Philos Sci*. 1948;15(2),100-103.