IAA Journal of Biological Sciences 13(1):16-22, 2025 www.iaajournals.org
©IAAJOURNALS ISSN:2636-7254
https://doi.org/10.59298/IAAJB/2025/1311622 IAAJB131

Ethical Considerations in Biomedical Engineering Research

Chelimo Faith Rebecca

Department of Clinical Medicine and Dentistry Kampala International University Uganda
Email: rebecca.chelimo@studwc.kiu.ac.ug

ABSTRACT

This paper examines the evolving ethical dimensions of art curation, emphasizing fairness, social justice, and professional responsibility in contemporary curatorial practices. From its historical roots in collection stewardship to its present role in cultural politics and digital representation, art curation increasingly engages with moral and philosophical challenges. Through thematic explorations ranging from curator roles, intellectual property rights, and technological influences, to case studies in representation and community impact, the study uncovers tensions between curatorial authority and public accountability. Commercialization, institutional interests, and cultural biases continue to challenge the neutrality and inclusivity of exhibitions. This paper argues that ethical curatorship must go beyond technical excellence to engage with the complexities of access, authenticity, historical justice, and collaborative community engagement. The discussion concludes with recommendations for ethical education and critical reflection to guide future curatorial strategies in a globalized, digitized, and ideologically contested art world.

Keywords: Art Curation Ethics, Curatorial Responsibility, Cultural Representation, Institutional Power, Visual Culture, Intellectual Property, Commercialization of Art.

INTRODUCTION

The term bioengineering refers to applied science that integrates biological sciences with physics, chemistry, and engineering to address biological challenges across five main areas: health-related issues, system manipulation, material extraction, biological entertainment, and system understanding. Biomedical engineering encompasses modeling aesthetic phenomena in fields like botany and architecture, and highlights life phenomena often overlooked by modern sciences. Bioengineering ethics focuses on the ethical implications arising from contemporary bioengineering advances, while its philosophical foundation includes non-biomedical engineering disciplines, as all engineering is ultimately technological. Biomedical engineering bioethics specifically addresses advanced issues within the broader bioengineering ethics framework, which encompasses all aspects of the field. Ethical considerations must encompass both classical and contemporary matters, with a focus on concerns relevant to biomedical engineering's various domains, such as oncology, genetic modification, and neural engineering. While biomedical engineering ethics is sometimes seen as constrained to standard biomedical ethics, this perception overlooks its broader context. The ethical dimensions of bioengineering extend to examining the potential negative impacts of various biotechnologies on human health, with bioethics serving as a crucial element in evaluating these technological advancements [1, 2].

Historical Context of Ethics in Biomedical Engineering

Ethics represent compulsory moral principles in specific fields. Engineering ethics emphasizes responsible practices impacting society and the environment. Phase I clinical trials assess the safety, dosage, and pharmacodynamics of new drugs in a small group. In malignant diseases, ethical considerations are crucial. Unlike standard mechanical testing, which requires a simple test matrix, the ethical implications in testing artificial joints with strain gauges differ significantly. Clinical ethics address the ethical aspects of Phase I trials, focusing on volunteer selection, side effects, and societal outcomes post-trial. Key concerns in clinical ethics include the side effects of drugs and devices within biomedical engineering. Research ethics pertain to the ethical conduct of scientists and engineers in this domain, particularly those

engaged in human-related studies. Research on non-living materials is generally separate from research ethics, resembling mechanical or civil engineering. Conversely, biological systems and health issues fall under bioethics, a philosophy focused on ethical dilemmas surrounding animal testing, cloning, and organ harvesting. Consequently, biomedical engineering, centered on biological phenomena, merges engineering ethics and bioethics [3, 4].

Key Ethical Principles

Concern for participant safety and well-being, stakeholder and community education and involvement, full disclosure of potential risks, benefits, and alterations of a human biomonitoring study, and clearly defined study goals, ranging from prevention of harm to basic knowledge, should be considered in the development and conduct of HBM. These issues, along with transparency and sharing human health data with the appropriate community, were elucidated in an ethical framework for HBM that was developed by the. The framework identifies three ethical principles to be considered when developing or undertaking human exposure investigations: beneficence, respect for persons, and justice. Beneficence calls for "actions that compel a positive obligation to protect, promote, or advance the well-being of others". This can occur through the actions of those conducting HBM or those who have a responsibility to develop, approve, fund, or otherwise oversee and support HBM. Respect for persons embodies the recognition of human dignity and the extension of that dignity to the community. Decisions before undertaking HBM studies must be made that balance the societal need for the information to protect public health against the potential for stigma and other consequences of public disclosure. While it has not been common in the past, some HBM studies now include stakeholder educational and participatory efforts upfront to assist in the study design. Decisions about whether and when to share data about individual participant results with members of the community are especially ethically fraught. It is inappropriate to share such data in a manner that a single identifiable result might be disclosed in a small community unless prior measures have been taken to ensure that the broader context, public health risk is present [5, 6].

Regulatory Frameworks

Biomedical engineering research represents a key transition from laboratory to clinic but faces ongoing and emerging ethical issues linked to new technologies. Ethical challenges span eight domains, including regulation, pre-clinical device testing, and technologies that regulate human biology, such as wearables and sensors. Topics also encompass 3D organ printing, automation impacts on workplace safety, commercialization challenges, intellectual property in synthetic biology, and the need for guidelines on cyber warfare and human enhancement. The academic biomedical engineering community must engage with these issues in research and policy. This field flourishes due to the demand for effective tools to treat human ailments, leveraging micro- and nano-level fabrication, deeper biological insights, and advanced imaging. Skilled engineers are vital for translating biological discoveries into practical solutions for patients and clinicians. As biotechnology applications expand, ethical and regulatory discussions must evolve to address the excitement and concerns associated with these advancements [7, 8].

Informed Consent in Biomedical Research

Research in laboratory medicine involves acquiring human biological material and data from subjects, necessitating informed consent. This process ensures participants are fully aware of the benefits and potential risks involved in the research. A signature confirming consent is required on a specific form, which is stored in the subject's medical and research files. Before research activities commence, the study must receive a verdict from the research ethics committee, known as ethics committee approval. Researchers in laboratory medicine must deepen their understanding of informed consent and ethics committee approval, which involves preparing a detailed application—a task that can be complex and varies by country due to differing ethical standards regarding human subjects. While this discussion centers on practices in Croatia, it aims to inform researchers in other areas and countries about legal requirements for these processes. The significance of informed consent and ethics committee approval in laboratory medicine is outlined, along with a detailed guide on navigating these processes. Additional notes on required actions, statements, and forms related to ethical research are included to enhance the quality of research in biomedical engineering and medicine [9, 10].

Ethics in Clinical Trials

The pattern is complicated further by the very different contexts of clinical trials in poor nations with first-generation and second-generation ICH guidelines. In nations with first-generation ICH guidelines, the ethics committees involved are mainly professional and academic, composed of people familiar with

bioethics, trial design, the history of the ICH process, and so on. In poorer nations where clinical trials occur under second-generation guidelines, the ethics boards are often highly politicised, and the ethical standards regrettably often low, with informal links to clinical/trial sites, taking weak informed consent, avoiding scrutiny, and often behaving as a trial sponsor's cheerleader. In the backdrop, decades of creativity and effort put into monumental texts on international bioethics have mostly gone unrealised. It is of concern that nations have blindly accepted and adopted ICH trial safeguards and assumptions which have not been proven, and exist in a context with very different socio-economic, political, and healthcare characteristics. Even if it is acknowledged that the strict ICH codes are impractical in poorer nations, it does not follow that the ethics committees can simply be bypassed. According to the simple logic of the ICH model, there is a set of questions to be asked and a human-level understanding acknowledged. They are: Why do trials in poor nations occur? By whom? For what benefits? With what safeguards? For how long? And at what prime cost? The onus rests with those wishing to undertake clinical research in poorer nations to demonstrate that the research satisfies these basic tenets. Otherwise, the ethics and morality of the proposed research should be vigorously and openly debated [11, 12].

Ethical Issues in Medical Devices

The past several decades have seen great advances in implantable and wearable medical technology. Devices previously imagined only in sci-fi movies are now a reality. Unfortunately, significant problems exist in the digital medicine device (DMD) realm that compromise the effectiveness of the technology and threaten user safety. Given that new technologies have unforeseen effects, there is a need for anticipated ethical issues to be assessed in the engineering design of new DMDs. Addressing ethical considerations may foster good DMD ideas, as it has been shown that applying ethical principles improves the design decisions of a system. The applicability of the same principles to DMD development could be imagined. However, these principles would have to be applied not only to device manufacturers but also to relevant stakeholder groups of patients, medical device companies, surgeons, and hospitals, as well as concerns that encompass the economic, regulatory, sustainability, and societal factors surrounding surgery. Moreover, healthcare considerations would need to be factored in. Some thoughts on key ethical considerations pertinent to the development of new embedded and IoT platforms for DMDs were presented. However, anticipated ethical issues for DMDs would need to consider the evolution of surgical considerations. The Anticipatory Technology Ethics (ATE) tool could be applied with its relevant mechanisms to forecast and deal with the inherent problem of uncertainty in technology development. It is recognized that a single ethical analysis tool is unlikely to be adequate for carrying out a comprehensive assessment of the range of divergent ethical dilemmas involved in the introduction and use of new DMDs. Furthermore, because these systems are highly complex, ethical analysis over DMD lifecycles should make use of a framework of multiple tools [13, 14].

Data Privacy and Security

Ensuring data privacy is essential to intellectual honesty and respect for intellectual property in biomedical engineering research, which often involves collecting sensitive health-related data from human subjects. This data can be particularly sensitive, especially when collected passively. Participants' involvement necessitates the use, storage, and transmission of such data, and breaches can cause irreparable harm, including discrimination or criminal liability. Many countries have regulations governing sensitive health data, and it is usually considered sensitive by default. Even without identifiers, reconstructing an individual's health details from a data set remains possible, underscoring the necessity for effective data management to mitigate risks. Researchers should create data management plans focusing on anonymization and security, adhering to privacy-by-design principles. Compliance-by-design approaches should also be considered to follow existing privacy laws. Researchers must remain vigilant about new vulnerabilities and technologies to enhance planning, risk assessment, and security. Stringent measures are particularly critical when handling extensive shared datasets and national or multinational databases, which require heightened security protocols. While sharing personally identifiable data may enable third-party analysis, it should be executed with caution, utilizing anonymization and data agglomeration techniques to reduce risks [15, 16].

Ethical Challenges in Genetic Engineering

Genetic engineering, in general, refers to a set of procedures where desired genes are selected from an organism and either re-inserted into the same organism or incorporated into another organism for that organism to express those specified genes. Currently, the most advanced type of genetic engineering is

the incorporation of new genes into an organism's cells and chromosomes. This general process is referred to as transgenics and is being applied to members of a wide range of species, from mice to plants to whales. Improving crops, creating models for human disease, and generating transgenic mice that develop pathologies closely mimicking those of human neurological disorders are just a few examples of the numerous uses of genetic engineering. With the completion of the Human Genome Project, biomedical research entered a new era defined by an explosive growth in functional knowledge of human genes, proteins, and metabolites. Unsurprisingly, however, this progress in functional knowledge generated a worrying set of ethical considerations, many of which revolve around transgenics and the potential human use of genetic engineering. Biomedical research is exciting and is pushing the boundaries of current human knowledge in unprecedented ways. Unfortunately, many of these radical breakthroughs come with ethical considerations that are too extreme for current society to grasp. In the modern context of the biomedical engineering revolution, there is simply not a large enough sense of urgency to grasp the radical implications and properly account for them in policy. In addition, as with many advanced but ethically contested technologies, it is difficult to formulate the questions that should be the basis for government investigation. For example, how can humans ever be prepared to fully consider the ethical pitfalls of using such powerful tools? Should more easy-to-implement technologies, such as drugs or behavioral modification, be tried before drastic genetic alterations? Are the dangers of improving human intelligence and regulating the birth of profoundly clever or retarded individuals comparable? All of these risks and applications tend to reside uncomfortably in the realm of fiction, or at least the not-so-near future. Ethics, however, are always grounded in something tangible; they are always applied in the here and now. It is critical that patience and the recognition of the reality of human genetic engineering not outstrip thoughtfulness in grappling with its radical implications [17, 18].

Cultural Considerations in Biomedical Research

Key ethical issues in biomedical research outside the US include assessing the research relevance and intervention standards. Historically, such research has benefited the conductors, often at the expense of participants. Some countries become targets of research deemed ethically unacceptable in wealthier nations, leading to potential harm to unwilling participants. Ethical dilemmas may also conflict with local laws. Embedding research in a local context is essential, including an understanding of cultural dynamics and stakeholder power. In the US, health care research ethics are well established, often involving partnerships between universities and health organizations. Many biomedical research sites in low- and middle-income countries lack proper accreditation. Creating a local IRB agreement is crucial to ensure ethical guidance and adaptation of research methods. Cultural awareness is vital, necessitating bi- or tri-lingual documents that clearly explain the study's rationale and methods while obtaining participants' consent. Input from a local biostatistician is also recommended, along with conducting a pilot test of the survey before the study begins. After obtaining consent, a debriefing should follow to confirm participants' understanding of the survey and its completion rules [19, 20].

Public Engagement and Ethical Discourse

Public engagement in microbiology research allows researchers to understand the knowledge, attitudes, and behaviors of the public, crucial for designing studies, recruitment, and trial conduct. Successful activities include recruitment, addressing patient information needs, consulting on ethical implications, and responding to outbreaks. Challenges remain, including limited resources and a lack of effective engagement strategies. Globally, community engagement in health research is vital, supported by a systematic review identifying goals and approaches, though it often presents ethical dilemmas and misconduct risks. As research evolves, especially with patient-centered methods, public engagement becomes more complex. Early engagement is essential to gather perspectives on proposed activities and to co-design responsible engagement strategies. Biomedical Engineering (BME) research is growing in Singapore, but there is limited public engagement to discuss these areas. This study aimed to explore effective public engagement regarding BME research. Three focus groups with 26 participants aged 22 to 78 discussed 11 BME research examples. Key topics included the need for consultation and oversight, questions about timing for consent processes, and concerns regarding technologies like nanotechnology and biobanking, which were perceived as a reservoir of biomedical data waiting to be exploited [21, 22].

Case Studies in Biomedical Ethics

Consider hypothetical biomedical engineering case studies involving nanotechnology, human enhancement, and genetics to foster discussions. A group of graduate students has funding to study nano-

particulate titanium dioxide toxicity, while a scientist at a technology transfer university is developing a product that may expose workers to these particulates. Should the students share findings about the mutagenic and cytotoxic effects of nano-titanium dioxide on human lung cells? If the students also performed a complementary in vitro study with preliminary data, could a joint publication benefit both parties despite claims about data ownership? If collaborations stem from funding and participation across departments, publication should ideally reflect shared contributions. Meanwhile, a biomedical engineer questions how far one would go to enhance a newborn's behavior and performance, humorously suggesting sending notices about enhancing neurochemical systems to bioethics exhibitors for a first birthday. This highlights the complex ethical implications of gene therapy and embryo selection based on traits perceived to promote happiness, such as intelligence and sociability. They ponder the challenges of ensuring desired traits if such genetic manipulation were feasible and the considerations required for altering children in this manner [23, 24].

Future Directions in Biomedical Engineering Ethics

Biomedical engineering significantly enhances the quality of life for countless individuals, merging the principles of engineering with cutting-edge medical technologies to facilitate unprecedented advances in the field of medicine. This innovative discipline plays a crucial role in aiding the restoration of bodily functions, replacing vital organs, and developing non-invasive medical procedures that are often less risky for patients. However, the rise and integration of these advanced technologies inevitably bring forth a plethora of significant ethical challenges that cannot be overlooked. To create biomedical technologies that are ethically sound and in alignment with established bioethical standards, it is imperative to thoroughly analyze the existing issues, identify potential concerns, and establish a comprehensive guiding ethical framework. Research ethics can greatly vary across different scientific disciplines, and biomedical engineering, being an inherently interdisciplinary field, is confronted with a diverse array of ethical matters that demand careful consideration. It is essential to establish a robust and comprehensive ethical framework that encompasses general ethical principles, specific ethical issues, and the roles of authoritative bodies that oversee biomedical practices and innovations. While the concept of 'bioengineering' includes the merging of biological sciences with engineering principles and their various applications, it is critical to understand that the ethical considerations associated with biotechnology fall under the broader umbrella of biomedical ethics. Discussions surrounding the future of clinical research ethics highlight that the ethical considerations specifically related to biomedical engineering can differ markedly from those found in traditional medical research, mainly due to the fundamental nature of what is being studied. Unlike living beings, engineered systems and bio-hybrid devices do not possess comparable mental capacities, making the ethical implications surrounding their use and development distinctly unique. Thus, a careful deliberation of these factors is vital for advancing ethical practices in biomedical engineering [25-31].

CONCLUSION

The ethics of art curation occupy a pivotal space at the intersection of cultural stewardship, artistic expression, and social responsibility. As curators navigate evolving technologies, shifting political landscapes, and commercial pressures, the ethical stakes of their work deepen. This study has shown that curatorial decisions ranging from art selection and exhibition framing to audience engagement are inherently political acts of representation. They influence who is seen, whose stories are told, and how history is interpreted. The growing prominence of curators in public discourse necessitates a renewed commitment to ethical integrity, transparency, and critical self-awareness. Future curatorial practices must prioritize inclusivity, fairness, and dialogue, especially in addressing historical injustices and expanding access to underrepresented voices. Ethical curation, when guided by reflective practice and public accountability, has the potential not only to preserve cultural heritage but also to foster transformative understanding across communities and generations.

REFERENCES

1. Bhambri P, Rani S. Bioengineering and healthcare data analysis: introduction, advances, and challenges. In: *Computational Intelligence and Blockchain in Biomedical and Health Informatics*. Cham: Springer; 2024. p. 1–25.
2. Winet H. Ethics for bioengineering scientists: treating data as clients. 2021;1–18 pp. Available from: [HTML].

3. Shogar IA. The philosophical foundations of modern bioengineering. 2017;1–45 pp. Available from: [PDF].
4. Hahm KH, Lee I. Biomedical ethics policy in Korea: characteristics and historical development. *Account Resour Health Policy*. 2012;10(1):23–38. Available from: ncbi.nlm.nih.gov.
5. Zölzer F, Zölzer N. The role of empathy in ethics of radiological protection. *J Radiol Prot*. 2022;42(4):701–14.
6. Ugwu CN, Ugwu OP, Alum EU, Eze VH, Basajja M, Ugwu JN, Ogenyi FC, Ejemot-Nwadiaro RI, Okon MB, Egba SI, Uti DE. Medical preparedness for bioterrorism and chemical warfare: A public health integration review. Medicine. 2025 May 2;104(18):e42289.
7. International Commission on Radiological Protection Publication 157. Ethics in radiological protection for medical diagnosis and treatment. *Ann ICRP*. 2024;53(1):1–72.
8. Selormey E. An evaluation of ethical concerns raised by a Ghanaian research ethics committee using Emanuel et al. benchmarks. 2015;1–60 pp. Available from: [PDF].
9. Nyamboga TO, Ugwu OP, Ugwu JN, Alum EU, Eze VH, Ugwu CN, Ogenyi FC, Okon MB, Ejemot-Nwadiaro RI. Biotechnological innovations in soil health management: a systematic review of integrating microbiome engineering, bioinformatics, and sustainable practices. Cogent Food & Agriculture. 2025 Dec 31;11(1):2519811.
10. Reichel J. Alternative rule-making within European bioethics – necessary and therefore legitimate? 2016;1–30 pp. Available from: [PDF].
11. Borovečki A, Mlinarić A, Horvat M, Šupak Smolčić V. Informed consent and ethics committee approval in laboratory medicine. 2018;1–20 pp. Available from: [PDF].
12. Cini E. Informed consent in clinical studies. 2018;1–25 pp. Available from: [PDF].
13. Josephson A, Smale M. What do you mean by "informed consent"? Ethics in economic development research. *Appl Econ Perspect Policy*. 2021 Dec;43(4):1305–29.
14. Ugwu CN, Ugwu OP, Alum EU, Eze VH, Basajja M, Ugwu JN, Ogenyi FC, Ejemot-Nwadiaro RI, Okon MB, Egba SI, Uti DE. Sustainable development goals (SDGs) and resilient healthcare systems: Addressing medicine and public health challenges in conflict zones. Medicine. 2025 Feb 14;104(7):e41535.
15. Lipphardt V, Surdu M, Ellebrecht N, Pfaffelhuber P, Wienroth M, Rappold GA. Europe's Roma people are vulnerable to poor practice in genetics. *Nature*. 2021 Nov 18;599(7885):368–71.
16. Brey P, Dainow B. Ethics by design for artificial intelligence. *AI Ethics*. 2024;4(2):199–211.
17. Tossell CC, Tenhundfeld NL, Momen A, Cooley K, de Visser EJ. Student perceptions of ChatGPT use in a college essay assignment: implications for learning, grading, and trust in artificial intelligence. *IEEE Trans Learn Technol*. 2024 Jan 16;17(1):1069–81.
18. Yang A, Pan ML, Lu HH, Lien CY, Wang DW, Chen CH. Assessing the evolution and influence of medical open databases on biomedical research and healthcare innovation: a 25-year perspective with a focus on privacy and privacy-enhancing technologies. *JMIR Med Inform*. 2024;194:eXXXX.
19. Tendulkar S. Leveraging machine learning in biomedical engineering to enhance medical device precision and cloud data security. 2024;1–15 pp. Available from: researchgate.net.
20. Babale YK, Atoi EN. Ethical concerns and risk perceptions associated with the application of genetic engineering. *NIU J Soc Sci*. 2021;11(2):45–57.
21. Nicholl DST. An introduction to genetic engineering. 2023;1–117 pp. Available from: 117.250.119.200.
22. Shamsi-Gooshki E, Parsapoor A, Moosavi S. Ethical challenges in conducting research in low- and middle-income settings during public health emergencies: qualitative evidence from the COVID-19 pandemic. *BMC Med Ethics*. 2025;26(1):12.
23. Eldridge L, Goodman NR, Chtourou A, Galassi A, Monge C, Cira MK, Pearlman PC, Loehrer PJ, Gopal S, Ginsburg O. Barriers and opportunities for cancer clinical trials in low- and middle-income countries. *JAMA Netw Open*. 2025 Apr 1;8(4):e257733.

24. Ugwu OP, Alum EU, Ugwu JN, Eze VH, Ugwu CN, Ogenyi FC, Okon MB. Harnessing technology for infectious disease response in conflict zones: Challenges, innovations, and policy implications. Medicine. 2024 Jul 12;103(28):e38834.
25. Sanchez TW, Brenman M, Ye X. The ethical concerns of artificial intelligence in urban planning. *J Am Plan Assoc*. 2025 Apr 3;91(2):294–307.
26. McKeown A, Mourby M, Harrison P, Walker S, Sheehan M, Singh I. Ethical issues in consent for the reuse of data in health data platforms. *Sci Eng Ethics*. 2021 Feb;27(1):1–21.
27. Hunt C, Montgomery S, Berkenpas JW, Sigafoos N, Oakley JC, Espinosa J, Justice N, Kishaba K, Hippe K, Si D, Hou J. Recent progress of machine learning in gene therapy. *Curr Gene Ther*. 2022 Apr 1;22(2):132–43.
28. Ongesa TN, Ugwu OP, Ugwu CN, Alum EU, Eze VH, Basajja M, Ugwu JN, Ogenyi FC, Okon MB, Ejemot-Nwadiaro RI. Optimizing emergency response systems in urban health crises: A project management approach to public health preparedness and response. Medicine. 2025 Jan 17;104(3):e41279.
29. Piergentili R, Del Rio A, Signore F, Umani Ronchi F, Marinelli E, Zaami S. CRISPR-Cas and its wide-ranging applications: from human genome editing to environmental implications, technical limitations, hazards and bioethical issues. *Cells*. 2021 Apr 21;10(5):969.
30. Cabrera J, Loyola MS, Magaña I, Rojas R. Ethical dilemmas, mental health, artificial intelligence, and LLM-based chatbots. In: *Int Work-Conf Bioinform Biomed Eng*. Cham: Springer Nature; 2023 Jun 29. p. 313–26.
31. Cheng K, Li Z, Li C, Xie R, Guo Q, He Y, Wu H. The potential of GPT-4 as an AI-powered virtual assistant for surgeons specialized in joint arthroplasty. *Ann Biomed Eng*. 2023 Jul;51(7):1366–70.

CITE AS: Chelimo Faith Rebecca (2025). Ethical Considerations in Biomedical Engineering Research. IAA Journal of Biological Sciences 13(1):16-22. https://doi.org/10.59298/IAAJB/2025/1311622