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Creating Bioethics Distance Learning Through Virtual Reality

Antoine L. Harfouche¹,* and Farid Nakhle¹

Bioethics education is a central element in the biotechnology curriculum. Re-imagining distance learning, virtual reality (VR) is taking student involvement to the next level of interaction, offering a real classroom experience and a new way to gain ethical reasoning skills. Here, we explore a new paradigm for bioethics education that involves VR.

Elevating Bioethics in Biotechnology Education

Science and ethics have been inextricably intertwined since the first expression of the Hippocratic oath [1]. Biotechnology is a powerful enterprise that can be harnessed to improve people’s lives in fundamental ways and on a global scale. Despite the many ways in which biotechnology breakthroughs have improved life, they cannot be viewed as unequivocally beneficial or even value neutral. As biotechnology gains momentum, so do issues concerning its ethical and social implications around the world. These ethical considerations have led to the design of frameworks within which biotechnology can be developed in socially acceptable ways [2].

Therefore, it is imperative to teach bioethics in higher education to help biotechnology students navigate ethical dilemmas early on in their career. Bioethics education is in high demand globally and has become a cornerstone of 21st-century education.

The term ‘bioethics’, which addresses the ethics relevant to biological knowledge and the science of living systems, is popularly attributed to Van Rensselaer Potter and first appeared institutionally in the USA in 1971, when Georgetown University established the Joseph and Rose Kennedy Institute for the Study of Human Reproduction and Bioethics [3]. Principlism is an important approach to ethics and, in bioethics, it includes the following core principles: respect for autonomy, beneficence, nonmaleficence, and justice [4]. However, while principlism can be important in helping students approach ethical dilemmas from a structured approach, it alone is not sufficient to address the many ethical dilemmas that arise from biotechnology.

The purpose of bioethics education in a biotechnology curriculum is to adequately equip students to unpack the various significant factors in an ethical dilemma, to weigh the ethically acceptable actions and their consequences, to balance benefits and risks of decisions, and to choose one that is most ethically and socially responsible. Bioethics education provides learners at all levels (biotechnology students, future scientists, and the new generation of aspiring innovators and bioentrepreneurs) a rich store of knowledge and a foundation for the development of creative critical thinking and ethical reasoning skills to support bioethical decision-making. Bioethics education can allow students to delve into the intricacies surrounding the ethical, legal, and social implications (ELSI) of biotechnology research. ELSI aims to further the conversation among stakeholders in the interactions among science, technology, and society [5]. This learning can also help to develop and reinforce bioethical values that can guide actions toward socially appropriate outcomes and strengthen biotechnology research ethics systems at scale. For some students, bioethics will become a lifelong vocation.

Virtual Reality for Quality Teaching and Learning

The concept of VR technology can be traced back to the 1960s, when Ivan Sutherland described VR as a window through which participants perceive the virtual environment as if looked, felt, sounded real, and in which they could act realistically [6]; currently, it is experiencing a renaissance of development and consumer interest among educators in distance learning.

In a modern world with diverse opportunities to innovate, technology is shaping the future of education by continuously establishing...
## Table I. Representative VR Technologies for Teaching and Learning

| VR platform  | Content sharing | Means of communication | World building support | Accessibility | Supported operating systems | Supported VR headsets | Website |
|--------------|-----------------|------------------------|------------------------|---------------|------------------------------|------------------------|---------|
| AltSpaceVR*  | Web content via browser† | Voice, text messages, emojis | Yes | Free | Microsoft Windows, Android | HTC Vive, Oculus Rift, Oculus Go, Oculus Quest, Samsung Gear VR | Altvr.com |
| Engage§      | Whiteboard, images, videos, PDF, presentations | Voice | No | Free | Microsoft Windows, Android | All HTC, Oculus Rift, Oculus Rift S, Oculus Quest, Valve Index, Pico G2, Pico Neo 2 | Engagevr.io |
| Rumii*       | Screen sharing, whiteboard, images, videos, PDF, 3D models | Voice, text messages | No | Free | Microsoft Windows, macOS, Android | HTC Vive, HTC Vive Pro, all Oculus | Dogheadsimulations.com/rumii |
| Mozilla Hubs* | Screen sharing | Voice, text messages, emojis | Yes | Free, open source‡ | Any OS with browser support | Any headset with browser support | Hubs.mozilla.com |
| Glue         | Images, videos, 3D models | Voice | Yes | Paid | Microsoft Windows, macOS, Android | HTC Vive, HTC Vive Pro, Valve Index, Oculus Rift, Oculus Rift S, Oculus Quest | Glue.work |
| Immersed     | Screen sharing, whiteboard | Voice | No | Free version, paid features | Microsoft Windows, macOS, macOS, Ubuntu Linux | Oculus Go, Oculus Quest | Immersedvr.com |
| meetingRoom  | Whiteboard, PDF | Voice | No | Free version, paid features | Microsoft Windows, macOS, Android, iOS | HTC Vive, HTC Vive Focus, all Oculus, all Pico | Meetingroom.io |
| Spatial      | Web content via browser, screen sharing, 3D models | Voice | No | Free version, paid features | Microsoft Windows, Android | Oculus Quest, HoloLens | Spatial.io |
| Wonda VR     | Screen sharing, images, videos, 3D models | Voice, text messages | Yes | Free version, paid features | Microsoft Windows, Android | HTC Headsets, Oculus Rift, Oculus Go, Oculus Quest, all Pico | Wondavr.com |
| vTime        | Images | Voice, text messages | No | Free | Microsoft Windows, Android | Oculus Rift, Oculus Go, Google Cardboard, Google Daydream, Samsung Gear VR | Vtime.net |
| MeetinVR     | Web content via browser, whiteboard, 3D models | Voice | No | Free | Microsoft Windows, Android | HTC Vive, Oculus Rift, Oculus Rift S, Oculus Quest | Meetinvr.net |

*Inside VR platforms, students are represented by customizable avatars. However, the Spatial platform automatically generates a custom avatar based on a photograph of the student’s face. All listed platforms were developed within the past 5 years.

†VR platforms make it possible to live stream and record classes to streaming platforms such as YouTube, Twitch, and Facebook.

‡Content sharing allows the ability to display multimedia content on a projection screen.

§World building allows educators to easily build and customize their own personalized classrooms.

*Educational communities, such as Educators in VR, make use of these platforms to host events for educators and learners to prepare them for the use of immersive technologies in education. Joining Educators in VR led the Bioethics class to adopt AltSpaceVR as its hosting platform. In conjunction with Educators in VR, the Immersive Learning Research Network (iLRN) is hosting its 2020 annual conference in VR to provide training support to educators enabling them to implement VR in their courses.

†Sharing content via browser allows educators and students to share screen, whiteboards, presentations, documents, and videos.

‡HTC, high-tech computer corporation.

Open source software is code that is designed to be publicly accessible: anyone can see, modify, and distribute the code as they see fit. It is developed in a collaborative way, relying on peer review and community production.
new tools and platforms in a student’s learning experience. When it comes to human-computer interaction, VR is different from other forms since students and educators participate in the virtual world rather than use it.

An expression attributed to Benjamin Franklin, a statesman and scientist who was one of the leading figures of early American history, encapsulates an influential approach to education: ‘tell me and I forget, teach me and I may remember, involve me and I learn’. Franklin claimed involvement was the key to learning. Therefore, online learning environments must allow students to interact with each other and with teachers to help simulate an immersive experiential learning.

Figure I. Bioethics Virtual Reality (VR) Classroom. The classroom serves as an interactive lecturing space. Teaching materials, such as presentations, documents, or videos, are projected onto the central screen. Students in VR are represented by customizable avatars that allow them to take on a virtual persona, which facilitates social interactions to boost their confidence, especially for those who may have difficulty with face-to-face communication. Teachers in VR have exclusive access to a variety of ‘host tools’ that assist them in class management. These include a ‘mute all’ button to limit distracting sounds, a ‘message all’ button to text all students in class at once, a megaphone button to amplify the microphone, a stage-blocking toggle to allow students access to the stage, giving them the opportunity to play a teacher role, and an audience participation panel that gives teachers the ability to see students who have raised their hands, allowing them a turn to speak. As for the students, several engaging actions enable them to interact with teachers and with each other: the microphone toggle to mute or unmute their microphone, an emojis panel to express their understanding and to visually interact with the teachers and each other, a floating web browser that enables students to navigate to any content of interest to their learning class that can also be shared to display its content for everyone in the classroom, and a raise hand button that reflects students intent to ask a question.
Box 2. Bioethics Breakout Teams: Team-Based Learning in VR

The Bioethics of a COVID-19 Vaccine: A Case Study

COVID-19 is an infectious disease caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which was unknown before the outbreak began in Wuhan, China, in December 2019. The virus was declared a pandemic by the World Health Organization (WHO) in March 2020. Governments around the globe established coronavirus action plans comprising several stages that embrace, among others, research and innovation, which are essential ingredients for progress toward generating unique solutions, including vaccines.

However, while biotechnological research is on the front lines of beating back COVID-19, success will depend on its ability to reinforce ethical values. Here, we summarize key ethical considerations drawing on the findings of in-depth inquiries conducted by the bioethics breakout teams in VR (Figure I). To vary group composition and increase diversity, students were randomly assigned to three groups of six using an in-house developed algorithm.

Team Balancing Risks and Benefits

Through VR teamwork, students critically reasoned the right balance between benefits and risks of developing vaccines at pandemic speed. Clinical trials involving small numbers of people first look for adverse effects and immune responses only. Speeding COVID-19 vaccine testing by deliberately infecting volunteers may seem highly unethical. Safety and whether individual volunteers fully understand the risks are paramount ethical concerns.

The team envisioned that the way in which risk-benefit assessments are conducted should be globally standardized and fully transparent. They also proposed that clinical trial volunteers should have a definitive say in deciding benefits and risks. When it comes to testing an experimental vaccine, urgency and speed are considered enemies of safety and mitigation of risk; the team reasoned that there should be a limit to acceptable risk, but this remains challenging. Volunteer clinical trials should only involve participants who have a relatively low risk of death or of severe complications from the disease. Volunteers need to be assured that they would have immediate access to intensive care and any available vaccines if they were to become infected.

Given the risks and uncertainties of these trials, the team concluded that fast-track regulatory approval of an efficacious vaccine could be ethically acceptable in some circumstances and commands enormous societal value.

Team Prioritizing Stakeholders

In this scenario, the world’s science enterprise is challenged by a global pandemic. Public and philanthropic health funds are the backbone of the underlying science that is needed to develop COVID-19 vaccines. However, making vaccines available is not only a scientific challenge.

The breakout team in VR envisioned that rich governments around the globe should not let the private market sort out the details of who gets access to the vaccine and at what price. Instead, they must be prepared to support the necessary technology transfer arrangements that include humanitarian clauses in their licensing agreements to ensure fair global access, especially to the poorest countries.

Developing an effective vaccine to prevent people getting COVID-19 and curb human-to-human transmission requires urgent global collective action from governments, philanthropies, industry, academia, foundations, and public-private partnerships for building large-scale manufacturing capacity. The team proposed that all stakeholders involved should do everything feasible to recognize the importance of treating society responsibly by developing a COVID-19 vaccine available to everyone worldwide if they are to bring the pandemic to an end.

Team Bioethical Decision-Making Model

The team in the VR breakout room read accounts of the race to develop a vaccine to protect against COVID-19 and considered the relevant ethical and social implications. Using a bioethical decision-making model, the team identified the ethical questions, listed the most relevant facts, examined bioethical issues from the viewpoint of stakeholders, considered values, and brainstormed possible solutions to dilemmas that arose from vaccine development.

There is much hope and excitement surrounding the development of COVID-19 vaccine. There are also important questions to consider, such as how to ensure ethically responsible use of COVID-19 vaccine and how to carve a path toward a global social acceptance?

This team proposed, in close collaboration with the other teams, a model demanding that researchers, innovators, stakeholders, funders, and policymakers are transparent and share knowledge with parallel COVID-19 vaccine efforts worldwide. The bioethical decision-making model team envisioned a public forum where everyone who is developing COVID-19 vaccines can gather and present their development plans and findings. It is crucial for governments to enact safeguards that ensure the vaccines are affordable and accessible to the people and health systems that need them, and not in the form of high profits for private companies. This would carve a path toward a shared global goal of COVID-19 prevention through ethically and socially responsible vaccination.

Emerging VR systems have applications that span education, training, and communication, among others [7]. The areas of application of VR in education are vast (reviewed in [8]). VR is an exceptionally promising immersive and interactive technology for the enhancement of the distance-learning process. It can confer many learning benefits in complex topics, such as bioethics, which demands a great level of understanding, due to its ability to help students reach their full potential. VR may hold great advantages for advancing bioethics distance education because participants can be immersed in a variety of situations that can aid understanding and promote practice and learning in ways that were not previously possible with traditional technologies (Boxes 1 and 2). VR also offers the potential to achieve an authentic experience and...
evoke realistic responses in students. It is fundamentally a reality simulator where participants can be immersed and empowered to learn from challenges and accomplish important and shared goals. Ideally, students sit in groups of six. The digital-inking whiteboard allows teams to iterate on ideas in real-time and to sketch with teammates, whether they are drawing, importing a presentation or a document, or typing text. It also helps introverted students participate in class. Consequently, students become more open to personal growth while engaging in relationships that they have with one another. Within the VR classroom, there is one projection screen and two desktop computers. The setup creates a digital triangle within the room. The computers can be used to access any content of interest to the case study. On the projection screen, materials and instructions related to the group task at hand can be displayed. The brainstorming roundtable prompts students to spark new ideas and empathize with each other. Students are also able to communicate by sending text messages to each other or to the teachers during a VR active learning session. The bulletin board provides a way to display relevant post-it notes and illustrations. Within the room, a coffee table serves as a hangout area where students can have virtual coffee breaks and helps to get them into a creative flow.

VR platforms (examples in Box 1) can bridge the gap between educators and learners and transform the way we teach and learn because it brings complex subject matter to life by creating 3D environments called ‘virtual worlds’. Compared with traditional 2D environments, virtual worlds add a spatial dimension in which students and educators are visually represented as avatars [10], while promoting the notion of collaborative learning where they learn together and often from each other [11]. Moving beyond the traditional classroom environment, the pedagogical benefits of VR offer effective learning to students through new ways of interaction in student-centered and teacher–student double-centered fashions.

Considering the impact VR can have on learning, and looking to add an extra dimension to bioethics course, we adopted AltspaceVR to educate the next generation of biotechnologists to think critically and creatively in exploring ethical situations in topical issues in biotechnology, and making informed decisions about those situations (see Figure I in Boxes 1 and 2). Integrating VR technology into bioethics education can improve the quality and outcomes of education programs by providing students with both an experiential learning component and educators to bring bioethics into the classroom in a cost-efficient way. VR technology is revolutionizing the digital learning experience, and we are only at the tip of the iceberg.
Fostering Creative Critical Thinking and Ethical Reasoning Skills Through Bioethics Education in VR Classrooms

As biotechnology advances, there is an increasing need for leaders who are able to think critically about the pressing ethical issues around it. The bioethics in VR course was designed to rigorously combine both foundational and practice-based learning experiences, including in-depth discussions of hypothetical and actual examples. The course demonstrated that students in VR have acquired extensive knowledge of current thinking in bioethics; have collected, synthesized, and critically reflected on ethical issues of biotechnology; and have developed ethical reasoning about the societal value of biotechnology. Lectures in VR additionally discussed ethical issues related to the safety implications of genetic engineering, genome editing, and gene therapy (see Figure I in Box 1).

Through the case-study method, we were able to teach ethical reasoning rather than just ethical principles. It is conceivable that the experience in bioethics in VR course also emboldened students by increasing their comfort levels in learning through doing, allowing them to feel at the center of the teacher’s attention (see Figure I in Box 2).

By using VR, we developed new bioethics immersive teaching and learning communities, and empowered them to apply their theoretical knowledge to practical endeavors in a multitude of settings inside and outside the VR space.

Promoting Ethical Decision-Making in VR Classrooms

Ethical issues are a growing concern for bioscience research development and enterprise. Using the bioethics of a coronavirus 2019 (COVID-19) vaccine case study (Box 2), students practiced how to develop an ethical decision-making model using a six-step approach. The case study was coded on three themes: balancing risks and benefits, prioritizing stakeholders, and the bioethical decision-making model. In VR breakout rooms, students listed the relevant facts, identified stakeholders, clarified the underlying values, weighed the risks against the benefits, developed a list of potential responses, and considered the best action (Box 2).

VR encouraged a deeper level of interaction, exploration, and curiosity-driven action among students, which are essential ingredients to learn ethical decision-making. The case-study component of the VR course provided the students with an opportunity to practice the development of bioethical decision-making models. What was fascinating about this virtual space was that all digital engagement happened in real-time, with the teacher explaining, guiding, asking, illustrating, and answering students’ questions. Our experience suggests that VR will have a sustained impact on the way teaching ethical decision-making is done, prompt new education advances, and improve educational outcomes.

Concluding Remarks

VR is more than just a tool for driving bioethics distance-learning innovations; it is also useful for motivating students, encouraging interactive learning, and developing ethical critical thinking and ethical decision-making skills. While VR can help boost the learning process, combining virtual and augmented reality will create significantly better returns on innovation.

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Engineering Microbes for Remediation of Oil Sands Tailings

Parisa Chegounian 1,2,*, Hisham Zerif 3,5,*, and Vikramaditya G. Yadav 1,2,4,6,*,

Synthetic biology and adaptive laboratory evolution are key tools for developing biotechnology platforms for the remediation of oil sands tailings. However, field deployment and subsequent regulation of engineered and/or evolved