PGET

PREPARING FOR HUMAN GENOME EDITING TECHNOLOGIES

Framing Our Biological Futures: Preliminary Results from Human Gene Editing Public Forums

March 2022

Baylor College of Medicine

ASU

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Executive Summary

The incredible potential and rapid advancement of gene editing techniques, particularly the invention of the CRISPR/Cas9 system, have raised significant ethical, legal, and social questions that cannot be answered by expert stakeholders alone. Baylor College of Medicine, Arizona State University, and the Museum of Science Boston (MOS), supported by the National Institutes of Health, worked with citizens and expert stakeholders to understand the driving forces behind human genome editing (HGE) research. The team developed a series of public deliberations around the ethics and governance of genome editing, and plan to use those results to inform policy. This report summarizes the methodology and preliminary findings from four public deliberation forums.

Using a reflexive public engagement method known as participatory technology assessment (pTA), three in-person forums in Boston, MA; Phoenix, AZ; and Waco, TX and one virtual forum with informed and demographically diverse participants across the United States were conducted to understand public concerns, values, and issues, and develop actionable understandings of public preferences regarding governance of HGE research, development and applications. The learning and engagement materials for these forums were created through literature review, expert interviews, expert workshops, and open-framed focus groups.

In total, 150 people participated across the four forums. The participants were majority female (54%) and white (58%) between the ages 25-44 (34%). In terms of self-identified political ideology, participants were primarily liberal (45%) or moderate (30%), and most considered faith important (31%) or very important (23%).

Our preliminary results found the following.

Comparing pre- and post-survey results, participants overall became less accepting of HGE applications for cosmetic and enhancements after the forums. Overall, they increasingly agreed that human genome editing should be regulated. The participants believed that the public has valuable input for decision-making, but there are limited opportunities for the public to participate in those decisions in the United States.

Participants' attitudes toward HGE can be broken down according to specific applications. When framed as a form of treatment or prevention, participants had only positive attitudes. They had a variety of attitudes toward enhancement and germline applications of HGE. Most participants found these applications problematic. Somatic applications were rarely mentioned; however, they had many concerns and hopes with respect to germline editing. Multiple concerns were expressed including future persons' autonomy, longevity of (negative) unintended effects, irreversibility, safety, enhancement, and playing God or interfering with nature. Hopes for germline editing were fewer in number but included greater research and regulation of the application, proceeding cautiously with it, and using it for beneficent reasons.

When considering the unintended effects of HGE, participants' responses coalesced around four main themes: inevitability, optimism, uncertainty, and the price of scientific progress.

Using expert interviews and engagement, we developed four scenarios of how a world with HGE might plausibly come to be in the year 2040 with different power structures and driving interests in each scenario. Participants were given one of the four scenarios to consider in-depth. Across all four scenarios, participants consistently noted the double-edged aspect that only some populations will benefit from HGE (e.g., those who are rich or powerful) leading to or exacerbating societal inequalities, especially in terms of access to the technology. The advantages and disadvantages that publics found across these plausible futures indicate their desire: 1) to improve human health via treatment, prevention, or eradication of disease; and 2) for oversight and regulation of HGE. Moreover, the disadvantages that publics noted in these plausible futures indicate their concerns over the misuse or abuse of these technologies, potentially including military or enhancement applications.

Consensus across the majority of participants indicated that they would like to see research on HGE proceed. However, participant approval was dependent on research meeting conditions for oversight, distribution, and an evaluation of societal impacts. Generally, participants indicated that HGE practice should be restricted to qualified researchers and scientists and placed a heavy emphasis on regulation, oversight, and technical expertise. The Department of Defense and private industry were the most contested among different funding categories. There was strong support for transparency, justice and equity as guiding principles for HGE decision-making.

Participants' hopes clustered around improvements in individual quality of life, decreased suffering and, in some cases, a decreased use of the healthcare system. Participant concerns, on the other hand, clustered around larger scale societal level risks of the research and population level unintended consequence. The focus on individual benefit, alongside concern for society-level risk, indicates that participants are hopeful of what HGE can offer in terms of health care, but desire vigilance in the face of potential societal level impacts.

Introduction

Project Background

Genome editing techniques have rapidly advanced in the past two decades. Recently, the CRISPR/Cas9 system has made this technology more accessible, precise, and less expensive. This has opened the door for wider use, but also raises significant ethical, legal, and social challenges, implicating questions of patient and population risk; normativity and marginalization; access to medicine and economic inequality; the morality of human modification or enhancement; ways of understanding and relating to human bodies and health; the political economy of research; democratic or other authority in and over innovation; biosecurity; and global governance, among others.

These issues cannot be solved by expert stakeholders alone. Recent National Academies reports on emerging genetic technologies have asserted that genome editing governance should be informed by substantive public engagement, dealing with "both facts and values[,] and in particular how anticipated changes will affect the things people value" (National Research Council 1996, p. 3; quoted in National Academies 2017, p. 127). Baylor College of Medicine, Arizona State University, and the Museum of Science Boston (MOS), supported by the National Institutes of Health (Project #1R01HG010332-01A1), worked with citizens and expert stakeholders to understand the driving forces behind human genome editing (HGE) research. The team developed a series of national citizen deliberations around the ethics and governance of genome editing, and plan to use those results to inform policy. This report explains the research aims and preliminary findings from four citizen deliberations.

Introduction

Project Aims

This NIH-sponsored research responds to the ethical, legal and social challenges through anticipatory governance, a suite of methods designed to build capacity for foresight, reflection, and flexibility in decision-makers and publics involved with emerging technologies. Public engagement and anticipatory knowledge generation aim to identify relevant public values; the ways in which different development and implementation trajectories could support or undercut such; and ways in which researchers, policymakers, and other involved parties may promote desirable over undesirable development pathways. In the HGE context, our project operationalizes anticipatory governance through three sequential aims:

AIM 1: Identify the social, ethical, and political driving forces and critical uncertainties relevant to HGE research and develop a set of plausible scenarios. Expert interviews informed an expert scenario workshop to develop a spread of plausible futures for HGE. In anticipatory governance, scenario development is intended not as prognostication but as an opportunity for critical reflection upon and articulation of the broader contexts, value tensions, and important potentialities of emerging technologies using a systems perspective.

AIM 2: Identify public values, beliefs, and concerns about the future of HGE. Using a reflexive public engagement method known as participatory technology assessment (pTA), three in-person public forums in Boston, MA; Phoenix, AZ; and Waco, TX and one virtual forum with participants across the United States were conducted to understand public concerns, values, and issues previously excluded from discussion, and develop actionable understandings of public preferences regarding governing HGE.

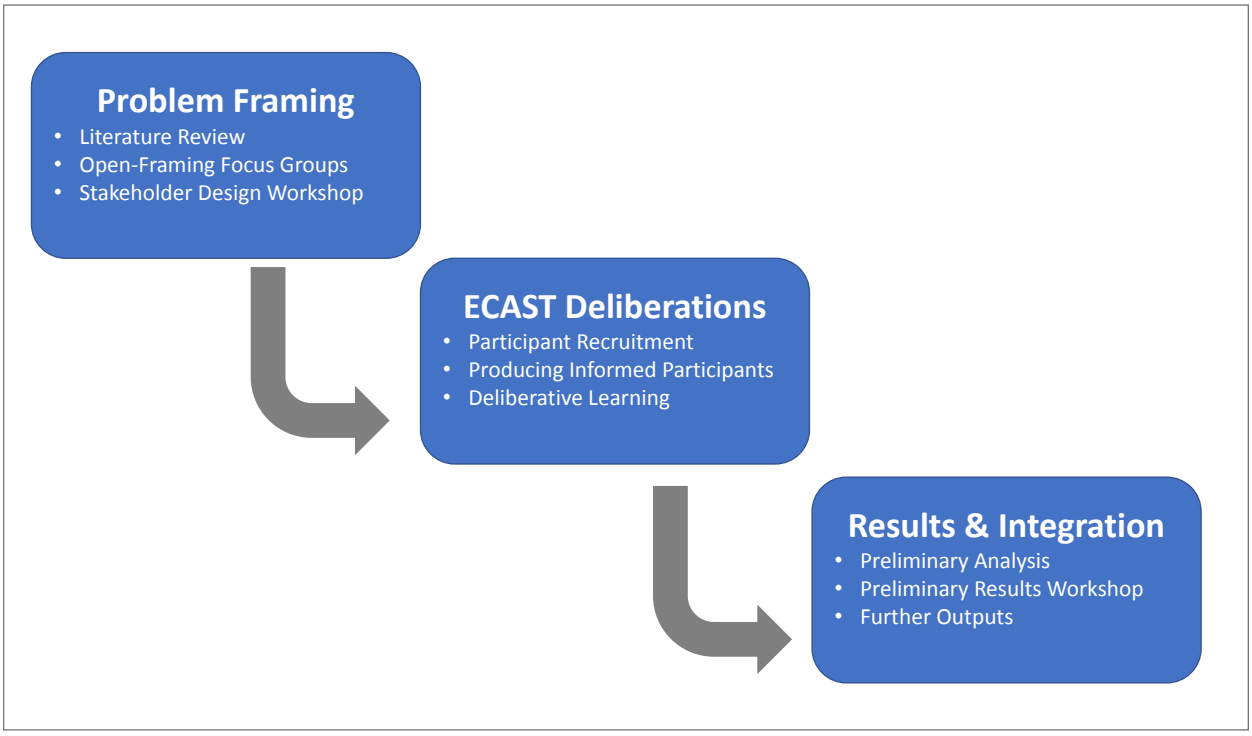
AIM 3: Synthesize outputs from Aims 1 and 2 to identify governance gaps, propose policy responses, and engage agencies and policymaking groups. We aim to identify urgent value tensions, governance gaps, and other priorities for governance, developing policy recommendations for their address and communicating our outputs to agencies, funders, and policymaking groups relevant to HGE.

Introduction

Participatory Technology Assessment (pTA)

Participatory technology assessment (pTA) refers to a class of methods used to bring public perspectives into critical science and technology decisions like HGE. To achieve the aims of this project, the team worked closely with the Expert and Citizen Assessment of Science and Technology (ECAST) network, a distributed group of academic, informal science education, citizen science, and non-partisan policy analysis programs and organizations.

The ECAST pTA is a reflexive, adaptable, and scalable method for democratic science policy decision-making (Kaplan et al., 2021). It consists of three participatory phases: 1) Problem Framing; 2) ECAST Deliberations; and 3) Results and Integration. Below is an overview of how the method is applied in general. Its specific applications to HGE are detailed in the later sections of this report.



ECAST pTA Method Steps

1. Problem Framing

Two participatory activities are combined to construct a balanced issue framing. Public concerns may not always align with those of experts and that an expert-designed series of questions can miss latent areas of public concern. The method thus utilizes an issue-framing process through use of open-framing focus groups. During these focus groups, 10-15 members of the public are provided with minimal background information and asked about their hopes and concerns regarding a HGE issue. These public perspectives are combined with expert framings extracted from a review of the academic literature and elicitation of expert and stakeholder perspectives during a stakeholder design workshop.

Introduction

2. ECAST Deliberation

Derived from the Danish Board of Technology's World Wide Views method of deliberation, ECAST deliberations consist of day-long, informed, multi-site deliberations with 80-100 members of the public. During the deliberation, participants sit at tables of 6-8 individuals with a neutral facilitator to guide the discussions through multiple sessions. The structure of each session is 1) watch a short briefing video, 2) engage in an interactive and facilitated table discussion regarding the session topic, and 3) complete a group activity and individual worksheet.

These deliberations are:

- Informed: Participants receive informational packets reviewing the issues, questions, and areas of uncertainty for HGE prior to the deliberation. They are also given additional information throughout the day in the form of videos, deliberation materials, and briefings to provide them with enough information to understand and discuss the topic. Providing this information creates empowered participants who feel ready to discuss a given issue at a high level.
- Diverse: Participants are recruited using online and traditional methods, and offered a stipend to incentivize participation. Selection is informed by population demographics but does not prioritize statistical representation. Instead, it strives for diversity of background, expertise and lived experiences relevant to the topic, bringing together a critical cross-section of the population of the city, state or country of focus.
- Interactive: Participants are divided into small groups where a neutral and trained facilitator guides them through a carefully designed bi-directional learning and engagement protocol. These are designed, developed, and evaluated by education professionals at science museums to make sure they are accessible and immersive. In addition to discussions, participants review cards depicting technology, stakeholder scenarios and other subjects of relevance and complete individual and group activities.

3. Results Integration

Both quantitative and qualitative data regarding public values and rationales are collected. Qualitative data includes written individual and group rationales, table observer notes and audio table recordings. Quantitative data includes pre and post surveys, individual worksheets, Likert-scale ratings and rankings, group ranking exercises, and demographic data. These data are analyzed using traditional methods of open and thematic coding. The statistical work is used to make sense of the data generated by the deliberations and to provide a general sense of the effectiveness of the forum. Since more data is collected than is possible to analyze in their entirety, preliminary results workshops are hosted to solicit expert and stakeholder input on areas for deeper analysis. This process helps to ensure the outputs of our deliberations are useful to policy and decision-makers.

Problem Framing

Aim I of the project sought to identify the social, ethical, and political driving forces and critical uncertainties relevant to HGE research and develop a set of plausible scenarios.

The following activities were conducted to meet this goal.

1. Literature Review & Expert Interviews.
2. Expert Scenario Development Workshop.
3. Open Framed Focus Group.

Literature Review & Expert Interviews

A structured, exhaustive review of HGE ethics, policy, and governance literature was conducted in the first stage of the project. The review examined both scholarly and gray literature. The search process yielded 133 documents, which were manually read and sorted for relevance. The purpose of the review was to survey expert discourse around genome editing ethics and governance, assess prior work in foresight and public engagement, and identify gaps to be filled with future work.

The general ethics and governance discourse separated HGE activities into three distinct stages of development (lab research, clinical research, and application) and prioritized values, interests, and representatives within each stage.

Development Stage	Lab Research	Clinical Research	General Application
Values Prioritized	Scientific Values • Knowledge development • Technical capacity development • Investment in research	Bioethics Values • Research subject & patient autonomy & safety • Biosecurity	Public Values • Treatment development • Public health • Human rights & dignity • Social solidarity • Social justice • Democratic control
Representatives	• Technical experts and practitioners • Professional associations	• Bioethicists • Regulatory bodies	• Indeterminate in literature • "Public engagement" • Elected officials?

The review found little formal, rigorous foresight scholarship in this realm. The closest form of foresight that exists in the literature is normative thought experiments; scholars pondering under what ideal hypothetical conditions would HGE be acceptable. However, the focus on what should happen does not help us understand the systems in which it currently is developing or how to prepare for the future that might happen.

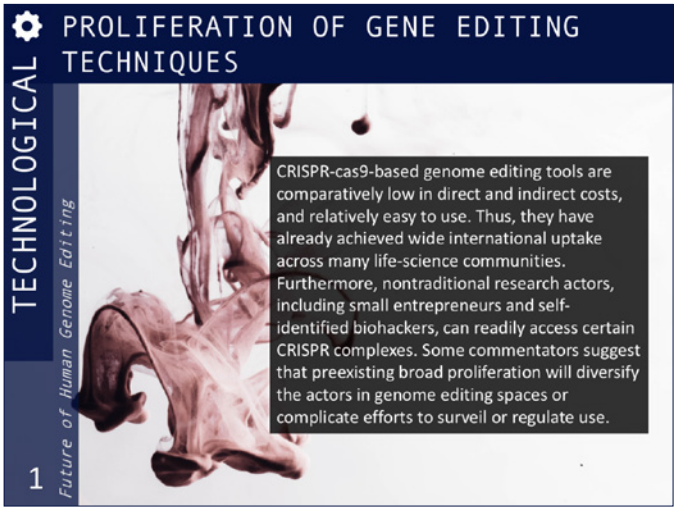
Similarly, the review found many calls for including public engagement in the development of HGE technologies but few operationalizations. What public engagement action has occurred has largely been in the form of public opinion polls about acceptance of the technology rather than truly understanding the public's needs, concerns, and values.

Problem Framing

The review found several gaps in the current scholarship that this project could fill. Broadly framed, deliberative public engagements rather than acceptance opinion polls are needed to truly engage and understand the public. These values should be considered further "upstream" in development of the technology in the lab and clinical research stages, rather than only considering them in application. Finally, rigorous foresight around what should, not just could, happen, is needed.

Based on the results of the survey, the project team conducted interviews with experts from a variety of technical and social disciplines. These 31 interviews with experts from a variety of technical and social disciplines explored a range of themes encompassing history, technology, economics, ethics, perceptions of socio-cultural environment, and governance. Based on these interviews and the literature review, more than 70 driving forces of change that might shape the future of HGE over the next twenty years were identified. Experts were invited to rank these drivers. The top ten were:

1. Proliferation of Genome Editing Technologies
2. Growing Distrust of Experts & Elite Institutions
3. Unauthorized Players & Rogue Actors
4. Eugenics & Population Control
5. Geopolitical Competition
6. Role of Militaries
7. Venture Capital in Healthcare
8. International Regulatory Differences
9. Rise in Nationalism & Authoritarianism
10. Disparities in Healthcare Access



Driver Card Examples

Problem Framing

Expert Scenario Development Workshop

Over a two-day virtual expert scenario development workshop involving many of the interviewed stakeholders, trained facilitators guided expert stakeholders through an interactive scenario development process. First, the group reflected upon the derived driver set, seeking those which were both impactful and uncertain. Based on this work, the group identified important "critical uncertainties", capturing some of the most important ways in which possible futures could differ. These two structuring variables were selected and crossed to provide a scaffolding around which to build four divergent and plausible scenarios for HGE in 2040. Participant subgroups worked to articulate each scenario's end state and the pathway from the present to the imagined future. Proceedings were recorded through audio and video capture, live dedicated note taking, and illustrative figures filled out by participants during deliberations.

Following the workshop, the core scenario team reviewed this captured material and elaborated the set of scenarios produced in the workshop. The draft scenarios were then vetted by the workshop participants who provided feedback on the challenge, plausibility, and relevance of each scenario.

Problem Framing

The scenarios and the central engine of each scenario were:

- The Wild Frontier – low regulation, uneven outcomes
- Slow and Steady – open innovation guided public values
- Safety First – early regulation; path dependent tech development
- Winner Takes All – unregulated; efficiency & private profit driven

These scenarios amplified tensions using hyperbole to spark new thinking and differentiation among the scenarios to create dynamism across the set. Each scenario highlights different key logics to the system and brings the reader into conversation with some of the ethical dilemmas that experts identified in future governance of HGE in pre-interviews, as well as during the workshop. They are intended to spark conversations and debates about the stakes, contexts, and potential consequences of different pathways for HGE. The scenarios are thus not designed as predictive tools, but exploratory, illustrative and evocative ones. Scenario development can thus reveal trends not well tended to, signal potential dangers and opportunities, highlight emerging relationships, and also identify points of leverage by which actors can work to promote desirable outcomes and mitigate undesirable ones.

Open Framed Focus Groups

The literature review and workshops allowed the project team to understand the issues as framed by the expert stakeholder community. What about the concerns and perspective of the public? In December 2020, we organized two open-framing focus groups to situate HGE innovations within the context of people's perspectives of the U.S. healthcare system. The open-framing technique is a deliberative public value mapping method that empowers lay people to set the agenda for emerging technologies. Studies have shown that if public engagement is too tightly framed around a particular technology, public opinion potentially becomes biased toward that technology and the pre-existing scientific commitments (Stirling 2008). Open-framing exercises help lay people situate emerging technologies in the broader context of the system it will influence (Bellamy et al. 2016, Macnaghten 2017).

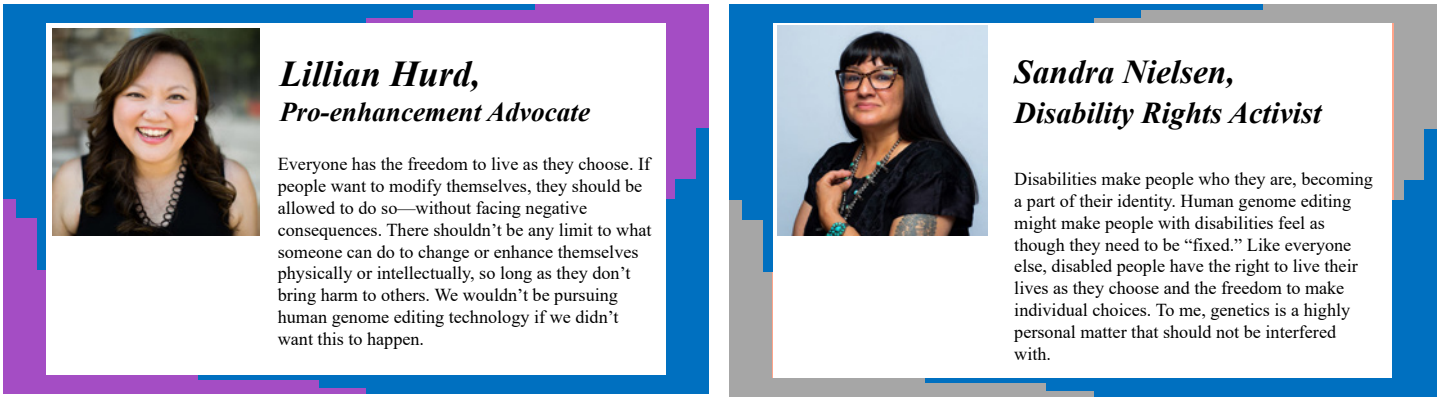
Due to the COVID-19 pandemic, the open-framed focus groups were conducted virtually via Zoom. The focus groups were conducted as two roughly 3-hour sessions over two back-to-back Saturdays. Participants were split into separate sessions with identical materials: Eastern and Central time zones in Session 1, and Mountain and Pacific time zones in Session 2. These accommodations were made to improve accessibility for participants rather than for comparative research purposes.

Participants were recruited by placing Craigslist ads in a variety of markets to cover an expansive and diverse cross-section from all regions of the United States. In order to frame the issue of HGE as broadly as possible, the recruitment materials stated that participants would share their thoughts on the healthcare system, healthcare innovations, and healthcare priorities, rather than HGE specifically. 44 participants were selected to participate, and 30 attended at least one day of the focus group. Throughout the focus groups, data was gathered by facilitators and individual worksheets.

Problem Framing

On day 1 of the focus group, participants were not aware that they would be discussing HGE. Before that discussion, which would take place on day 2, we wanted participants to focus on their broad experiences with the U.S. healthcare system. Working in facilitated groups of 4-6 people, participants reflected on their concerns with the healthcare system and identify their top five priorities for improving the healthcare system. Some common priorities were accessibility, cost, and equity. At the end of the session, participants were told that the next session would discuss HGE.

On the second day of the focus group, participants were given an introduction to HGE and provided viewpoints from various stakeholders. At the beginning of the session, participants watched a short video explaining the technology and its potential. They were also sent stakeholder cards to review as homework before the session. These stakeholder cards were created by conducting a literature review of concerns, motivations, and attitudes towards HGE in popular media, then creating fictional characters to represent prevailing themes.



Stakeholder Card Examples

After learning about HGE, participants were invited to share their top concerns. Participants expressed concerns about potential unintended consequences, malicious or weaponized use, amplification of class and racial divides, human enhancement, research ethics, and the need for regulations. After sharing their concerns, participants reflected on if and how HGE fit into their five priorities for the healthcare system from the previous day. Out of the six groups that participated, none saw HGE as a priority for improving healthcare. Some saw it as a potential healthcare choice within the system, but the prevailing concerns across all groups were accessibility and cost. As one group stated, "There are problems to solve within the system before this (HGE) is a major priority. People suffer and die from treatable diseases now due to lack of access."

Problem Framing

Forum Design Workshop

The results from the Aim I research were used to create an ECAST deliberation to fulfill Aim II. Members of the Aim II research team used the Aim I inputs to formulate research questions and develop which topics and issues should be discussed during the forum. These were used to design the forum flow, including questions for the participants, as well as characters who would bring up voices and concerns that might not otherwise enter the conversations, and activities to engage with topics like budget prioritization. The design went through formative evaluation, including two online focus groups, expert review, and perspective editors.

From the Aim I team, the Aim II team used the four future scenarios, as well as information about what kind of issues were important and should be covered. The scenarios were rewritten for a public audience, pulling out their most important aspects. Due to the amount of information participants were asked to ingest and retain during the 6-hour forum, each table only interacted with one of the four future scenarios.

In February of 2021, the Aim II team held a virtual expert design workshop which gathered experts in gene editing, ethics, and public engagement. These experts were introduced to the forum process, learned about the work done in Aim I, and were asked to respond to several topics that the Aim II team used to inform the forum design. These topics were HGE Foresight and Uncertainties, Social Implications, Governance, and Public Engagement Design. During breakout groups, facilitators and notetakers recorded the conversation. Experts were also asked to engage with pget.consider.it, a website providing more in-depth information for each of the topics and an opportunity to respond to drivers of change, ranking their importance and impact.

Following the Expert Design Workshop, members of the Aim II team performed a content analysis of the responses and conversations. These results were reviewed and, while considering research goals of the project team, the questions, and topics that the publics needed to engage with were determined. David Tomblin and Lauren Lambert used these conversations and results to develop the questions and overall flow for the forum. Janine Myszka used this information and discussions about what ethical considerations needed to be raised to develop six character narratives that would accomplish these goals, and created an agenda and facilitation guide for the forum. The forum design included the character narratives, scenarios, a budgeting activity, background information, and questions for individual and group response. A background information document was developed by John P. Nelson. This was adapted into a video script for forum participants by Janine Myszka.

From June – August 2021, the Museum of Science, Boston, recruited focus group participants from Craigslist and community partners to test the forum with people unfamiliar with gene editing technologies. Each focus group lasted about 5 hours over two days. Internal evaluator Sunewan Paneto led the evaluation for the focus groups, testing whether character cards were relatable and felt true to reality, participants had enough background information to fully engage in the conversation, and activities had the desired flow and outputs. To ensure the narratives in the character cards presented to public participants were true to lived experience, the Aim II team recruited perspective editors. Our editors included a Deaf woman, an Indigenous woman, and a Black community leader, all with relevant experience in the topic. The materials were also reviewed by members of MOS's Diversity, Equity, Accessibility and Inclusion team.

Graphic design was completed by a professional graphic designer with extensive experience in forum visual design, Malorie Landgreen of Colorbox Industries.

Forum Materials

A key element of the ECAST pTA deliberation model is creating informed participants. The following materials were provided to help participants understand the underlying technical aspects, salient issues, questions, and areas of uncertainty within HGE. An External Advisory Committee reviewed the materials to ensure they were accurate, accessible, balanced, and provided adequate information for participants to discuss the issues in an informed manner.

Forum Structure

Three in-person public forums were conducted in Boston, MA; Phoenix, AZ; and Waco, TX. To capture a wider swath of views, one virtual forum with participants across the United States was also conducted. The agenda was identical for all forums but the timing was altered for the online forums. For the in-person forums, participants joined for one six-hour day. For the online forum, the event was split over two days, breaking where the in-person participants had lunch.

	AGENDA
10:00-10:10	Introductions & Welcome
10:10-10:50	Part 1: Open Framing
10:50-11:45	Part 2: Human Genome Editing
11:45-11:55	Break
11:55-12:40	Part 3: Possible Futures
12:40-12:55	Share Out
12:55-1:40	Lunch
1:40-1:45	Welcome Back and overview of afternoon
1:45-3:00	Part 4: How Should We Make Decisions About HGE
3:00-3:10	Break
3:10-3:40	Part 5: Hopes and Concerns
3:40-3:55	Share Out
3:55-4:05	Thank you and send off

During the forums, participants were split into groups of 5-7 with an experienced facilitator at each table to guide the table discussions. Facilitators were provided the materials and facilitation guide prior to an online training where they were guided through the forum and offered opportunities to ask questions and share facilitation experiences.

Forum Materials

Background Materials

Participants were provided with a 22-page background document to help them have a base knowledge for discussion. The document contained information about what to expect at the forum, how the document was produced, and background information about HGE technologies. This background information included a primer on what genes are, what HGE is, some of the existing paradigms about how different kinds of editing are classified, an explanation of what is possible with HGE, and broader ethical considerations. The booklet also contained detailed information about all four scenarios developed by the experts in the Scenario Development workshop. During the forum, groups were assigned a single scenario to consider thoroughly.

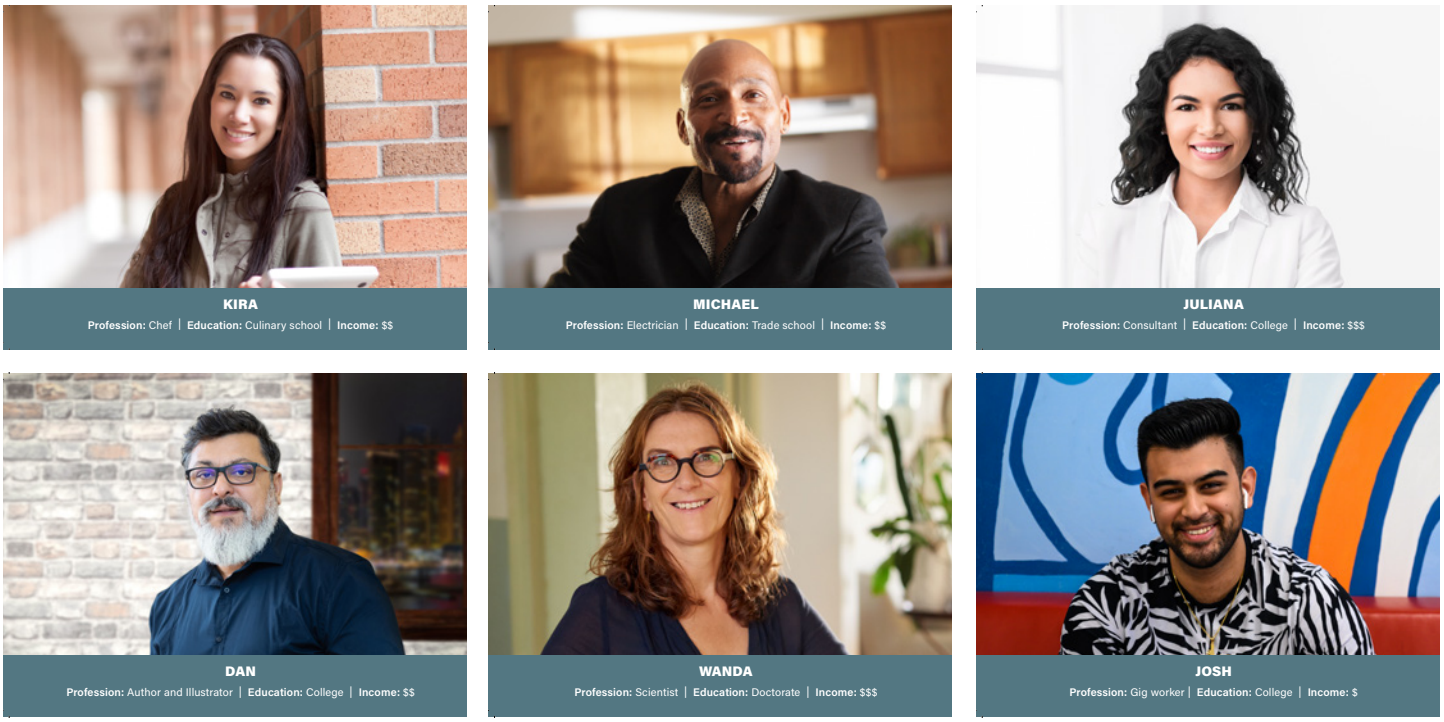
Cards

Participants encountered two types of cards during the forum: possible futures cards and character cards. Both kinds of cards underwent a review process from the External Advisory committee and were tested in a series of focus groups to ensure accessibility to a general audience. In addition, the character cards underwent perspective editing where members of the groups that the characters represented were invited to edit the cards to make sure they were reflective of lived experience.

Each group received only one of the possible futures cards which contained a summary of a future visioned by an expert workshop from Aim I of the research project. The language from the summary of those scenarios was adapted and shortened to be accessible to a lay audience.

Forum Materials

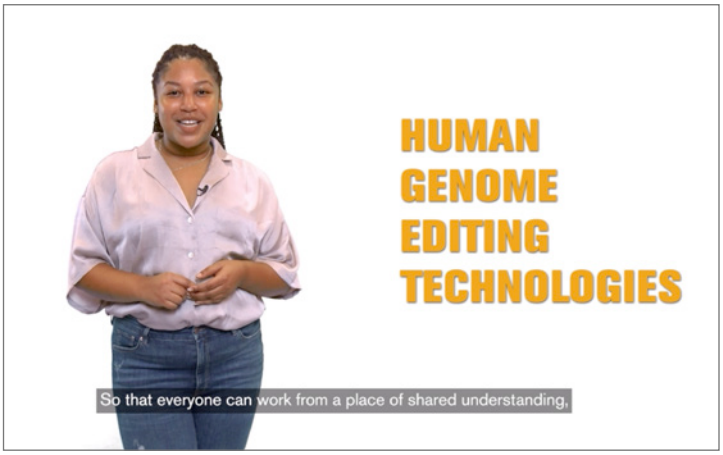
There were two sets of three character cards for a total of 6 characters. Each table received one of the two sets of character cards. This was done to determine if some topics only arose due to the cards. The cards were developed by first deciding what kinds of ethical dilemmas the research team wanted to show participants. Ultimately, the issues of disability, rare disease, indigenous values, funding, heritable editing, and making decisions for others were included in the cards. For each character, we found at least one perspective editor to ensure that the narrative put forth by the character was true to their lived experience. The cards attempted to show diversity in age, wealth, education, ability, and race.



Character Cards, Set 1 (Top) and Set 2 (Bottom)

Videos

Not all participants have the inclination or ability to read the background materials packet. To ensure that everyone has a baseline understanding of the material, a video was shown during the session. This video was substantively based on HGE information from the background packet, but with edits for time and flow. The video was filmed and edited by the audio-visual team at the MOS.



Preliminary Results

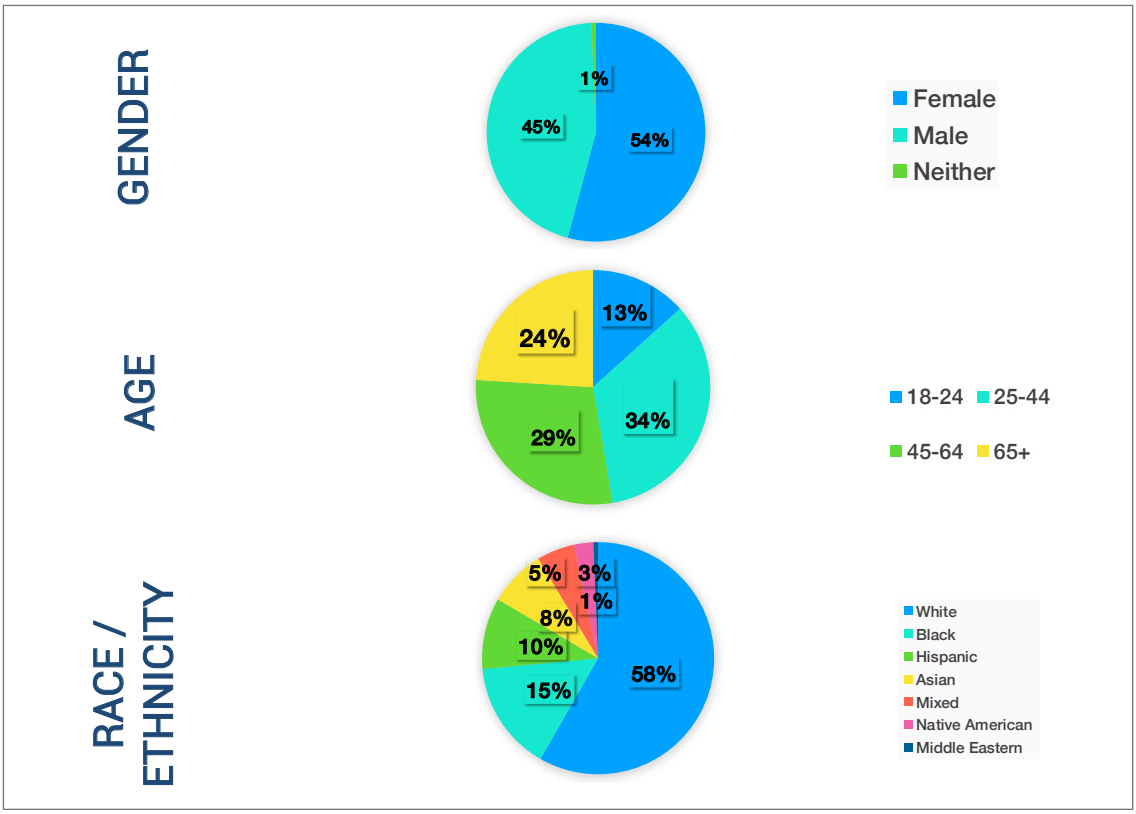
Data Collection Methods

Qualitative and quantitative data were collected in a variety of ways.

- Pre- and post-surveys to understand their change in opinions and attitudes, if any.
- Anonymized application demographic data
- Individual response sheets and workbooks
- Group responses and activities
- Table observer notes
- Table audio recordings

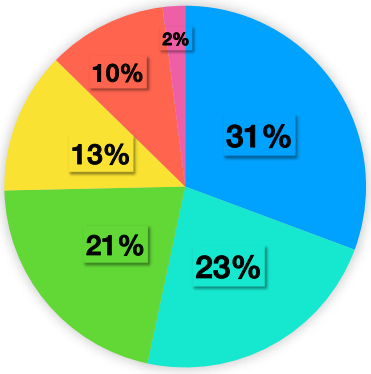
Who Participated?

The in-person forums were hosted at science museums in Boston, MA; Phoenix, AZ; and Waco, TX. Participants were recruited primarily through the science museum mailing lists, local stakeholder engagement, and Craigslist. Drawing on the science museum mailing lists led to an oversampling of liberal attitudes in the in-person forums. To gather a wider variety of views, the virtual forum intentionally recruited in primarily conservative regions by placing Craigslist advertisements in cities identified by a 2014 Pew Research article as "most conservative." 150 people participated across the four forums. More than half of the population was female (54%) and the majority of participants were between the ages 25-44 (34%) with the fewest in the age range of 18-24 (13%). The majority of participants identified as White (58%). The majority of participants found faith, religion or spirituality to be important (31%) or very important (23%). Most of the population considered themselves to be liberal (45%) or moderate (30%).



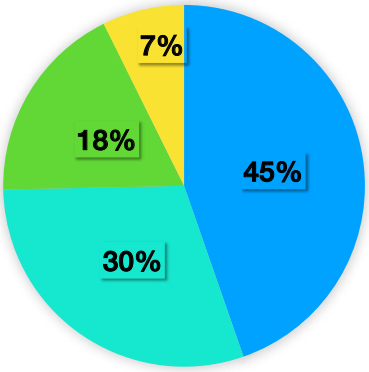
Preliminary Results

FAITH



Important
Very Important
Neutral
Not at all Important
Not Important
Prefer Not to Answer

POLITICAL IDEOLOGY



Liberal
Middle
Conservative
Don't Know/Other

Preliminary Results

Session 0. Pre-Survey & Post-Survey Data

Participants were given pre- and post-surveys in order to understand their personal opinions and attitudes towards HGE, science, and public engagement. Responses to the pre-survey and post-survey were compared to see if and how these opinions changed after the deliberations.

Question	Boston			Waco			Phoenix			Online		
	n	Pre-Avg	Post-Avg	n	Pre-Avg	Post-Avg	n	Pre-Avg	Post-Avg	n	Pre-Avg	Post-Avg
It is acceptable to use human genome editing to alter physical traits, such as hair or eye color.	41	2.46	2.17	31	3.06	2.32	51	2.86	2.45	24	4.000	2.93
It is acceptable to use human genome editing for enhancement of functioning, such as strength or vision.	41	3.88	2.90	31	3.68	2.84	51	3.55	2.90	14	4.71	5.14
It is acceptable to use human genome editing for cognitive enhancement, such as intelligence.	41	3.80	2.54	31	3.61	2.65	51	3.55	2.76	24	4.67	4.71
I think that human genome editing will become a common medical intervention in the future.	41	5.68	5.85	31	5.81	5.94	51	5.8	6.12	24	5.71	6.21
Human genome editing research should be regulated.	41	6.37	6.56	31	6.06	6.06	51	6.31	6.55	14	5.21	6.51

Participants ranked their answers from 1 (strongly disagree) to 7 (strongly agree). Attitudes shifted for the majority of the questions in the post-surveys.

Question 1: “It is acceptable to use human genome editing to alter physical traits such as hair or eye color.” They initially tended to agree with this comment and increasingly disagreed in the post-survey.

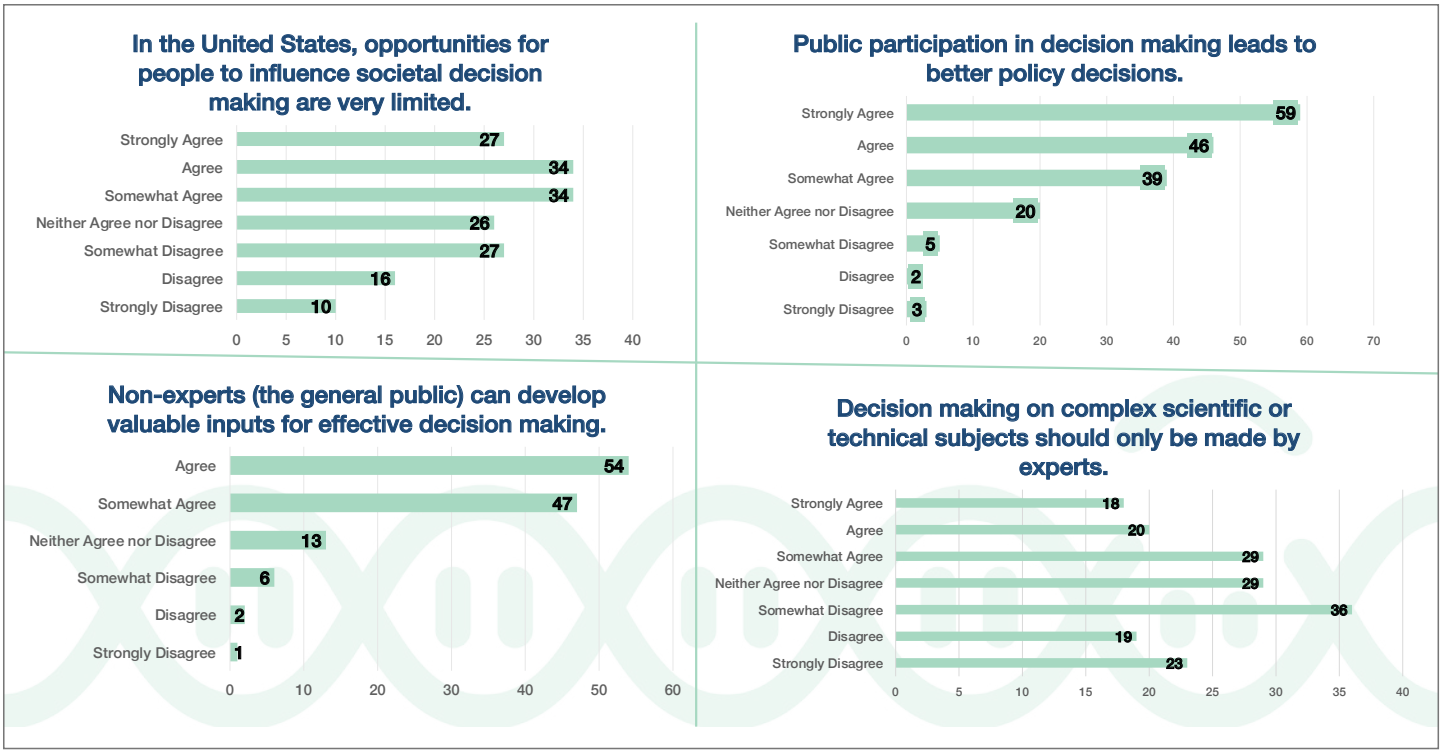
Question 2: “It is acceptable to use human genome editing for enhancement of functioning such as strength or vision.” The in-person groups increasingly disagreed with this statement in the post-survey; however, the online responses shifted towards more agreement.

Question 3: “It is acceptable to use human genome editing for cognitive enhancement such as intelligence.” The in-person groups increasingly disagreed with this statement in the post-survey; however, the online responses shifted towards more agreement.

Question 4: “I think human genome editing will become a common medical intervention in the future.” There was no significant difference for the statement. Averages in both pre- and post-surveys skewed towards agreement or somewhat agreement.

Question 5: “Human genome editing research should be regulated.” In all sites except for Waco in which averages remained the same, all increasingly agreed that human genome editing should be regulated.

Preliminary Results



When asked about decision-making procedures and public engagement, participants were in strong agreement that public participation leads to better policy decisions but most felt that opportunities for people to influence these decisions in the United States were limited. The overwhelming majority either agreed or somewhat agreed that the public can develop valuable inputs for effective decision-making. Lastly, corresponding with the rest of the data, the majority disagreed that decision-making on complex scientific or technical subjects should only be made by experts.

Summary

Participants were given pre- and post-surveys in order to understand their opinions on HGE and decision-making and see if their attitudes shifted post-deliberation.

With the exception of the virtual participants, participants overall became less accepting of HGE applications in the case of cosmetics and enhancements after the forums. Additionally, in all sites except Waco, in which attitudes remained the same, participants increasingly agreed that human genome editing should be regulated.

Most participants tended to agree or somewhat agree that in the US, opportunities for lay people to influence societal decision-making are very limited. The majority of participants tended to agree that the public would have valuable input for decision-making and should be able to participate in it.

Preliminary Results

Session 1. Open Framing

To ease forum participants into a full-day of deliberation on HGE, we started by asking them a simple, yet engaging question: How would you describe your experience with medical technologies?

Attitudes

- Participants were mostly positive towards medical technologies, focusing on their ease, speed, and safety.
- The second largest group of participants showed ambivalence towards medical technologies, noting both positive and negative aspects.
- A few participants felt negative about medical technologies, focusing on technical and human error in their appropriate use.
- One participant displayed an avoidant attitude towards medical technologies.

Expertise

- Several participants noted high expertise with medical technology.
- A few participants noted the low expertise or little experience they had with medical technology.
- A few participants noted their previous experience participating in a clinical trial.

Purpose of Technology

- Many participants noted using medical technology to diagnose conditions.
- Several participants noted using medical technology to treat conditions.
- A few participants noted using medical technology to prevent conditions.
- Several participants discussed their use of medical technology for monitoring one's health.
- A few participants mentioned the use of medical technology for maintaining one's health.
- Several participants noted the use of medical technology to improve one's quality of life.
- One participant mentioned using medical technology to improve performance.
- Several participants discuss medical technology in the context of saving life.
- A few participants mentioned using medical technology to find out about one's genetic predisposition to a condition.
- A few participants mentioned the use of medical technology for purposes of rehabilitation.
- A few participants noted the use of medical technology for reproductive or non-reproductive purposes.

Summary

Though most participants held positive attitudes toward medical technologies, a sizable portion felt ambivalent about them. Only a minority of participants held negative and avoidant attitudes towards medical technologies.

Multiple participants noted either high or low expertise with medical technologies. A few participants mentioned having previously participated in a clinical trial.

In their responses to the open framing question, participants refer to various purposes of medical technologies, most often describing diagnosis, treatment, or prevention of conditions as well as monitoring or maintaining one's health, improving quality of life, and saving life.

Preliminary Results

Session 2. Human Gene Editing

To ease forum participants into a full-day of deliberation on HGE, we started by asking them a simple, yet engaging question: How would you describe your experience with medical technologies?

After providing forum participants information about HGE and its various possible applications, we asked them to answer the following questions:

- *How do you feel about developing human gene editing therapies that could have multiple uses?*
- *How do you feel about the possibility of unintended effects?*
- *Would your views be any different if the effects could be passed onto future generations? Why?*

Collectively, these questions generated the following themes and subthemes.

Attitudes Toward Specific Applications

- *Treatment and/or Prevention*
  Many participants expressed positive attitudes for treatment and/or prevention, with a focus on cures, addressing debilitating illness or disease, and saving life.
- *Enhancement*
  Most participants expressed negative attitudes for enhancement, focusing on inequality, the creation of "super" humans, and eugenics. However, some participants expressed positive attitudes for enhancement, conditioned on the hope that such applications will be limited or monitored. One participant seemed ambivalent about applications for enhancement.
- *Somatic*
  Somatic applications were rarely mentioned.
- *Germline*
  Many participants expressed negative attitudes about germline editing, focusing on future persons' lack of autonomy with respect to these decisions and the potential for (greater) inequality. However, several participants shared a positive attitude toward germline, focusing on eradication or avoidance of hereditary disease and passing on benefits to future generations. One participant had an ambivalent attitude towards germline editing.

Unintended Effects

- Participants repeatedly discussed the inevitability of unintended effects with HGE.
- Several participants approached the topic of unintended effects with some optimism.
- A few participants also emphasized the aspect of uncertainty.
- Several participants framed unintended effects as the price of scientific progress.

Preliminary Results

Germline Editing

- *Concerns*
  The most common concern for germline editing was about future persons' autonomy. Another common concern with respect to germline editing was the longevity of (negative) unintended effects. Several participants noted concern over the irreversibility of germline editing. Several participants were concerned about germline editing's safety or potential for harm. A few participants raised concerns about germline editing's potential for enhancement. A few participants noted concern over playing god or interfering with nature when editing the germline.
- *Hopes*
  A common hope for germline editing was to conduct more research on the application. Another common hope for germline editing was for the implementation of regulation. Participants often expressed a desire to proceed cautiously with germline editing. Some participants emphasized wanting to use such applications specifically for beneficent reasons.

Summary

Participants' attitudes toward HGE can be broken down according to specific applications. Only positive attitudes were expressed about HGE when framed as a form of treatment or prevention. Further analysis is required to understand why participants rarely mentioned somatic applications of HGE. Participants had a variety of attitudes toward enhancement and germline applications of HGE. Most participants found these applications problematic. However, some participants viewed such applications as beneficial. Only rarely did participants express ambivalence about these applications.

When considering the unintended effects of HGE, participants' responses aggregated around four main themes: inevitability, optimism, uncertainty, and the price of scientific progress.

Participant responses also indicated concerns and hopes with respect to germline editing, an approach that would use HGE to edit human embryos, thereby introducing a heritable change in the genome. Multiple concerns included future persons' autonomy, longevity of (negative) unintended effects, irreversibility, safety, enhancement, and playing god or interfering with nature. Hopes for germline editing were fewer in number but included greater research and regulation of the application, proceeding cautiously with it, and using it for beneficent reasons.

Preliminary Results

Session 3. Possible Futures

During the first component of our project, in discussion with experts on HGE, we developed four scenarios of how a world with HGE might plausibly come to be. Factors shaping these possible futures include the interests driving development and use of HGE (i.e., market versus public interests) and distribution of power (i.e., among many actors/practitioners versus few actors/practitioners).

Forum participants were divided into multiple groups, with each assigned one of the four scenarios. Each scenario had a corresponding brief description and details on what people in that scenario know about HGE, who is in charge of it, who has access to it, how it is used, and who can provide it. Participants were then asked to consider: What are the advantages and disadvantages of the scenario and who experiences them?

THE WILD FRONTIER

In a world of rapid innovation, questioned expertise, and powerful market incentives, profitable technologies advance along with an explosion in human gene editing experimentation under highly variable rules.

SLOW AND STEADY

This is a world where science and technology are more open and governed democratically, rather than by those who have the most expertise or resources, and social values guide new innovations.

SAFETY FIRST

Moral and safety concerns result in more rules and governmental oversight, leading to a few globally dispersed and uncoordinated centers of excellence.

WINNER TAKES ALL

Never before seen corporate consolidation between information technology, biomedicine, and genomics firms leads to a rapid market and profit driven development of genome editing.

Possible Futures Cards

Preliminary Results

Wild Frontier

In a world of rapid innovation, questioned expertise, and powerful market incentives, profitable technologies advance along with an explosion in HGE experimentation under highly variable rules.

ADVANTAGES	DISADVANTAGES
Fits Capitalistic Framework	Profits Are Prioritized
Some Will Benefit	Unequal Access
Fast Growth	Lack of Oversight/Regulation – Safety Issues
Cures for Disease	Enhancement
	Misinformation

Slow and Steady

This is a world where science and technology are more open and governed democratically, rather than by those who have the most expertise or resources, and social values guide new innovations.

ADVANTAGES	DISADVANTAGES
Some Will Benefit	Unequal Access
Slow Pace	Slow Progress
Equitable Access	Limited Access
Global Oversight/Collaboration	Potential for Misuse/Abuse
Minimization of Risk	
Need-Based Prioritization	

Safety First

Moral and safety concerns result in more rules and government oversight, leading to a few globally dispersed and uncoordinated centers of excellence.

ADVANTAGES	DISADVANTAGES
Some Will Benefit	Inequality
Treatment for/Eradication of Disease	Unknown Effects
Better Human Health	Militization
Cures for Disease	Potential for Discrimination
	No Overall/Global Oversight/Regulation

Preliminary Results

Winner Takes All

Never-before-seen corporate consolidation between information technology, biomedicine, and genomics firms leads to a rapid market and profit-driven development of genome editing.

ADVANTAGES	DISADVANTAGES
Some Will Benefit	(Exacerbating) Inequalities
Fits Capitalist Framework	Profits Prioritized Over Beneficence
Disease Treated/Prevented/Cured	Potential for Misuse/Abuse
Fast Innovation	
Increased Longevity	

Summary

Despite the diverse plausible futures that may result from varying parameters, including interests driving development and use of HGE and distribution of power over these technologies, publics consistently noted, across all four scenarios, the double-edged aspect that only some populations will benefit from HGE (e.g., those who are rich or powerful) leading to or exacerbating societal inequalities, especially in terms of access to the technology. For the two scenarios that frame market interests as a driver of innovation and use of HGE (e.g., Wild Frontier and Winter Takes All), publics also noted the double-edged aspect that these worlds fit a capitalistic framework, thereby prioritizing profits over other worthwhile aims (e.g., what is best for minority groups or all of humanity). In the Slow and Steady scenario, publics additionally understood a slow pace to be advantageous in terms of preventing harm but also a hindrance in terms of only gradual progress. Additionally, publics noted that this world featured equitable albeit limited access to HGE.

The advantages and disadvantages that publics found across these plausible futures indicate their desire: 1) to improve human health via treatment, prevention, or eradication of disease; and 2) for oversight and regulation of HGE. Moreover, the disadvantages that publics noted in these plausible futures indicate their concerns over the misuse or abuse of these technologies, potentially including military or enhancement applications.

Preliminary Results

Session 4. How Should We Make Decisions about Human Genome Editing?

During this session, participants were posed on if research should proceed, who should conduct said research, how it should be regulated and funded, and what principles should be considered when designing research and regulations for HGE.

Should we proceed with research? If so, what should we proceed with?

The vast majority of participants voted yes (85.5%) to proceed with research. However, this included many conditions including oversight, evaluation of societal impacts, and equitable distribution.

In terms of what should we proceed with, all sites were consistent in what they thought were preferable and undesirable applications. The "treatment" application received support with very little qualification in the written responses. All the other applications—prevention, longevity, enhancement, and military use—received some conditional statements and reservations about moving forward. As for what we should not do, military applications and human enhancement were the only treatment types that received significant attention.

Who should be allowed to practice HGE?

Majority of the responses suggested that researchers and scientists are the only ones who should be allowed to practice HGE, with an emphasis on qualification, education, clinical knowledge, accreditation, individual moral qualifications, government regulation, institutional oversight, and assumptions regarding a lack of bias in the field of science.

What oversight and regulation should exist, if any?

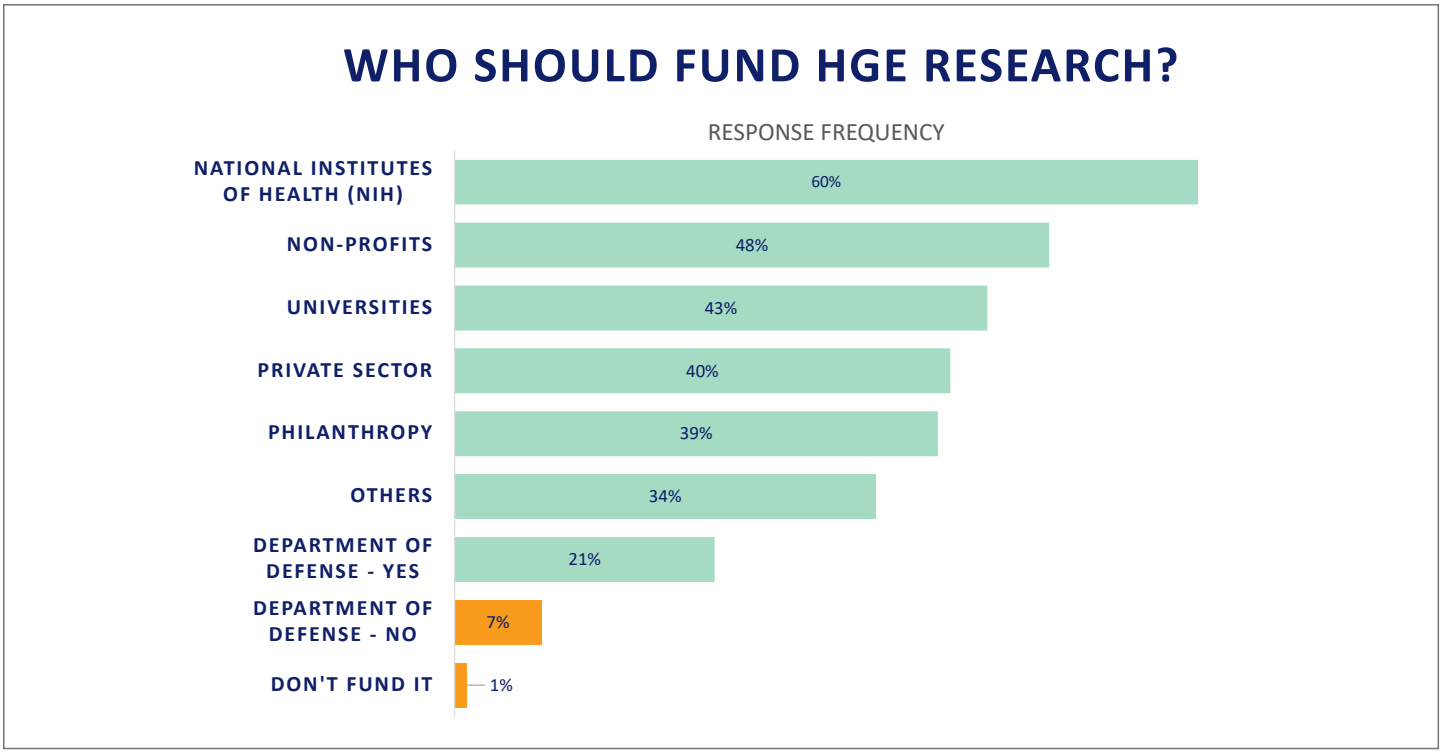
Generally, participants wanted to see HGE regulated. Their rationales fell into technical regulation, such as wanting only the best experts to be the ones practicing, or ethical regulation, such as wanting those "most likely to drive the research without personal bias" to be allowed to practice.

In addition to the current institutional frameworks and norms to regulate HGE, some participants suggested new, targeted types of regulations or new regulatory institutions, such as third party or global entities that could regulate HGE research and application. Those who suggested a new type of HGE specific oversight made suggestions for an international board, or global body, a new licensing global standard, a HGE specific consortium, which included articulation for both expert and citizen participation, as well as a more general concept for a new regulatory HGE specific group.

Who should fund HGE research?

The Department of Defense (DOD) was the only organization that was mentioned repeatedly in the negative. The second most contested category was the private sector where there were a range of responses both supporting and concerned about involvement from the private sector. One of the benefits that was touted was the financial incentive that pharmaceutical companies might have in pursuing HGE, and therefore would be positioned well to fund the research. Alternatively, many participants expressed conditionality in their acceptance of funding from the private sector, as well as concerns over corporate interests leading the direction of HGE.

Preliminary Results



What principles should be considered when making decisions about HGE research and regulations?
To answer this question, participants were asked to rank the values-based principles in the table below in the order in which they should be considered when making decisions. Several participants expressed that the exercise was very difficult and that most of these principles are important, while others went out of their way to dismiss certain principles.

Certain principles clustered together. For instance, transparency and justice cluster together (not significantly different) as the most supported guiding principles. But justice and equity also cluster, whereas equity is significantly different from transparency. Autonomy sits in the middle of all guiding principles by itself, while public engagement, enforcement, and flexibility cluster together as the least supported.

PRINCIPLE	AVERAGE SCORE
Transparency	2.77
Justice	3.12
Equity	3.49
Autonomy	4.04
Public Engagement	4.63
Enforcement	4.76
Flexibility	5.12

1 Most Important

7 Least Important

Preliminary Results

Summary

Consensus across the majority of participants indicated that they would like to see research on HGE proceed. However, participant approval was dependent on research meeting conditions for oversight, distribution, and an evaluation of societal impacts. Generally, participants indicated that researchers and scientists are the only ones who should be allowed to practice HGE and placed a heavy emphasis on regulation, oversight, and technical expertise. The Department of Defense and private industry were the most contested funding categories. Participant support for principles that should guide HGE decision-making clustered around transparency, justice and equity.

Preliminary Results

Session 5. Hopes and Concerns

In this session, participants were asked to share their top three hopes and concerns for the future of HGE.

Top Hopes

- Improve their quality of life
- Eliminate and cure diseases
- Be equally accessible to all members of society
- Decrease human suffering
- Lead to better treatments for conditions
- Prevent diseases
- Save lives
- Be used to eliminate inheritable diseases (both psychiatric and physical)

Hidden in the participants' responses about hopes were articulations of a desire for HGE to be effectively regulated and used responsibly (not in the hands of the "wrong" people), further emphasizing an underlying concern for ethics in the public positioning of a hopeful future for HGE.

Top Concerns

- Increases in inequality in society (either through enhancement, or unequal access to medical technology
- Weaponization or use by militaries for warfare
- Rogue research that is unregulated or DIY scientists that have gone "buckwild"
- HGE to be used for genocide or any type of eugenic control
- Generational level genetic damage
- Irreversible side effects
- Unintended health consequences
- Longevity enhancement and population increases
- Privacy
- Lack of transparent oversight in the research
- Population level genetic change

Population increases connected to longevity occurred as concerns articulated in two different lines of reasoning: 1) natural resource availability and longevity increasing leading to population growth that outpaces natural resource availability; and 2) concerns that social inequality could be experienced as wealthy individuals were able to increase the duration of their lives. These and other variations around the concern for longevity applications were mirrored elsewhere in participants' responses.

Less frequently mentioned, but significant nonetheless, are concerns that could impact the future of HGE and its development. These include statements about the morality of the research, the idea of future eugenics as it relates to social inequalities based on people who have received HGE that is preferred by the dominant society.

Preliminary Results

Summary
Participants' hopes clustered around improvements in individual quality of life, decreased suffering and, in some cases, a decreased use of the healthcare system. Participant concerns, on the other hand, clustered around larger scale societal level risks of the research and population level unintended consequence. The focus on individual benefit, alongside concern for society-level risk, indicates that participants are hopeful of what HGE can offer in terms of health care, but desired vigilance in the face of potential societal level impacts.

Next Steps

In our final aim, we will synthesize the outputs from Aims I and II to identify governance gaps, propose policy responses, and engage agencies and policymaking groups. These outputs will help identify urgent value tensions, governance gaps, and other priorities for governance, developing policy recommendations for their address and communicating our outputs to agencies, funders, and policymaking groups relevant to HGE.

As evidenced by the literature review, there is a lack of scholarly and applied effort on foresight and public engagement on HGE. Our outputs will be disseminated in various channels such as academic papers, policy briefs, and news stories to reach a wider audience for impact. This project is the first comprehensive, national foresight and public engagement initiative on HGE and the first end-to-end application of anticipatory governance, and as such serves as a demonstration of the value of the approach. The methods discovered and refined here can serve as a model for future engagements.

In addition to contributing to HGE policy, this project is intended to develop forward-looking, democratically derived, and ethically reflective processes useful in preparing for possible futures of emerging technologies more broadly. Such processes may help to support proactive rather than reactive science and technology policy, guided by sustained and substantive interchange between publics, experts, agencies, and institutions to improve connections between scientific practice and public values.

References

Bellamy R. A. (2016). A Sociotechnical Framework for Governing Climate Engineering. *Science, Technology, & Human Values*. 41(2):135-162.

Kaplan, L.R., M. Farooque, D. Sarewitz, & D. Tomblin (2021). Designing participatory technology assessments: A reflexive method for advancing the public role in science policy decision-making. *Technological Forecasting and Social Change* 171, 120974.

Macnaghten, Phil. (2017). Focus Groups as Anticipatory Methodology: A Contribution from Science and Technology Studies Towards Socially Resilient Governance. In Barbour, R.S. & Morgan D.L. (Eds), *A New Era in Focus Group Research* (pp.343-363). Palgrave Macmillan.

National Academies of Sciences, Engineering, and Medicine (2017). Human Genome Editing: Science, Ethics, and Governance. Washington, DC: The National Academies Press.