

People-oriented:

A Practical Guide to Social
Research in Synthetic Biology



People-oriented: A Practical Guide to Social Research in Synthetic Biology

Contact

Preface.....	3
1. Red Lines in Social Research.....	3
1.1 Legal Red Lines	4
1.1.1 Unlawful Collection of Sensitive Personal Information	4
1.1.2 Violations of Human Genetic Resources Management Regulations.....	4
1.1.3 Infringement of Privacy and Data Security.....	5
1.2 Ethical Red Lines: Protecting the Rights and Dignity of Respondents.....	6
1.2.1 Violations of the Principle of Informed Consent.....	6
1.2.2 Endangering the Physical and Mental Safety of Respondents	6
1.2.3 Exploitation of Vulnerable Groups or Special Groups.....	7
1.3 Biosafety Red Lines	7
1.3.1 Involvement in Illegal Biological Activities or Endangering Biosafety.....	7
1.3.2 Violations of Scientific Integrity	7
2. Communication Skills.....	8
2.1 Clarifying Objectives and Audiences.....	8
2.2 Communication Skills to Improve Reliability	9
2.2.1 Aligning Project Features with Interviewees' Interests in Communication.....	9
2.2.2 Clearly Defining Concepts to Avoid Ambiguity	9
2.2.3 Structured Follow-up to Verify Consistency	10
2.2.4 Immediate Clarification and Confirmation	10
2.2.5 Maintaining Neutrality and Reducing Suggestiveness.....	11
2.2.6 Building a Good Relationship and Encouraging Candor	11
2.3 Communication Skills to Improve Validity (Accuracy).....	12
2.3.1 In-depth Follow-up and the "Onion Peeling" Technique	12
2.3.2 Focusing on Behaviors and Specific Examples	12
2.3.3 Using Non-verbal Information for Insight and Follow-up.....	12
2.3.4 Challenging Assumptions and Exploring Contradictory Evidence	12
2.3.5 Contextualized Questioning	12
2.3.6 Distinguishing Between Facts and Opinions.....	12
2.4 Core Communication Principles Throughout the Process.....	12
2.4.1 Active Listening	13
2.4.2 Non-judgmental Attitude.....	15
2.5 Evaluation and Iteration: Continuously Optimizing Communication.....	16
3. Scientific Design of Synthetic Biology Questionnaires Based on the Principles of Reliability and Validity Assurance and Ethical Standards.....	17
3.1 Systematic Design for Reliability and Validity Assurance.....	17
3.1.1 Audience Stratification and Cognitive Matching	17

3.1.2 Questionnaire Length Control.....	19
3.1.3 Logical Progression of Questions	19
3.1.4 Scientific Inspection of Questions.....	19
3.1.5 Pre-research.....	20
3.2 Comprehensive Consolidation of Ethical Standards.....	20
3.2.1 Prioritizing a Sense of Security	20
3.2.2 Protection of Autonomy and Privacy	21
3.2.3 Feedback on Participation Value	21
3.2.4 Post-Survey Privacy Reinforcement	21
4.Theory and Strategies for In-depth Communication with Different Age Groups from the Perspective of Enhancing Reliability and Validity	22
4.1Under 18 Years Old.....	22
4.1.1 Age Group Characteristics	22
4.1.2 Relevant Research.....	22
4.1.3 Corresponding Strategies	22
4.2 18–25 Years Old.....	23
4.2.1 Age Group Characteristics	23
4.2.2 Relevant Research.....	23
4.2.3 Corresponding Strategies	23
4.3 26–55 Years Old.....	24
4.3.1 Age Group Characteristics	24
4.3.2 Relevant Research.....	24
4.3.3 Strategies.....	24
4.4 56 Years Old and Above.....	24
4.4.1 Age Group Characteristics	24
4.4.2 Relevant Research.....	25
4.4.3 Strategies.....	25
4.5 Techniques for Cross-Age Communication	25
5. Practice-Based Learning and Improvement	26
5.1 questionnaire	26
5.2 communication.....	27
References.....	27

Preface

Only when synthetic biology steps out of the laboratory and truly engages with human society—rather than just dealing with engineered bacteria and mammalian cells in the lab—does it form a grand system, a discipline that truly originates from and serves society.

This transition may make iGEMers who are accustomed to working in the laboratory feel overwhelmed, but it also brings significant hidden risks, particularly regarding the legitimacy of social research.

It is likely that most iGEMers will only realize the difference when they go out into society and communicate with people directly: the individual differences among people are far more complex than the processes of transcription and translation of proteins in *E. coli* in the laboratory.

This handbook aims to develop a two-way evaluation system and a guide for iGEMers for social research in the field of synthetic biology. Starting from the perspective of respondents and exploring the potential data in the information provided by them, it contributes a standardized guide for iGEMers' social research. It strives to improve the reliability and validity of information in social research while protecting the psychological well-being of respondents.

This guide is very user-friendly for those actively involved in social research and is designed to address most social research issues. Before its publication, this guide underwent multiple revisions and received feedback within our team. We have also put it into practice in our own social research and gained valuable experience, ensuring that each item of this guide is effectively applicable to social research in synthetic biology. However, this does not mean that the handbook is exhaustive. iGEMers in different countries still need to conduct in-depth analysis based on the specific cultural and folk customs of their respective countries.

This handbook is organized according to the following logic:

First, we need to clarify the work that should be done to ensure the mental health of respondents in social research and prevent them from feeling that their privacy has been violated.

Second, on the premise of ensuring the psychological safety of respondents, we will explore how to improve the reliability and validity of information through communication skills.

Third, we will discuss how to scientifically design questionnaires to ensure reliability, validity, and compliance with ethical and moral standards.

Fourth, we will elaborate on the universal approaches that can be adopted for in-depth communication with different age groups to obtain more information with high reliability and validity.

Finally, we will append the problems encountered in our social research projects and the measures taken to optimize this guide, so as to ensure the practicality and feasibility of the guide.

1. Red Lines in Social Research

When conducting social research related to biological issues, biotherapies, or human physical

conditions in the field of synthetic biology, it is essential to strictly comply with internationally accepted laws and regulations, recognized ethical guidelines, and industry standards. All relevant activities must undergo ethical review, with the protection of participants as the top priority, and any unethical behavior must be firmly prohibited. This principle has been widely recognized by international organizations such as the United Nations Educational, Scientific and Cultural Organization (UNESCO), the World Health Organization (WHO), and the Organization for Economic Co-operation and Development (OECD). Its core legal basis includes the protection of personal dignity as stipulated in the Universal Declaration of Human Rights, as well as a series of international conventions and guidelines specifically addressing bioethics and data security.

1.1 Legal Red Lines

1.1.1 Unlawful Collection of Sensitive Personal Information

International regulations explicitly prohibit the collection of personal biological information (e.g., genetic sequences, medical history, and familial genetic data) without valid consent. Such data may only be obtained with the explicit and separate authorization of participants and must be strictly limited to the scope necessary for research purposes. Under the EU's General Data Protection Regulation (GDPR)[1], biometric data is classified as a "special category of personal data" and is prohibited from processing except under strictly defined exceptions such as "explicit consent" or "safeguarding substantial public interests." Moreover, a Data Protection Impact Assessment (DPIA) must be conducted and documented in advance.

The European Data Protection Board (EDPB) emphasizes the principle of data minimization, requiring the use of less intrusive alternatives where possible and mandating that data be stored in systems where participants retain direct control over encryption keys to avoid the risks associated with centralized databases.

World Medical Association (WMA) "Helsinki Declaration"[2] stipulates that genetic information collection must prioritize participant interests, prohibiting broader genetic testing beyond research objectives. For minors, dual consent from both guardians and the minors themselves (where capable of understanding) is required. The Council for International Organizations of Medical Sciences (CIOMS)[3] guidelines prohibit the acquisition of biological data through deception, concealment of research purposes, or coercion. Researchers must clearly inform participants in writing of data usage, storage duration, and sharing scope. Participants retain the right to withdraw consent at any time and request data deletion.

1.1.2 Violations of Human Genetic Resources Management Regulations

The international community takes "shared sovereignty and safe and controllable management" as the core principles for the management of human genetic resources. The Council of Europe's Oviedo Convention (adopted in 1997 and entered into force in 2000)[4], as the world's first legally binding bioethics convention, clearly stipulates that each country has sovereignty over the human genetic resources within its borders. Transnational research must obtain written approval from the competent authorities of the country where the resources are located, and foreign institutions are not allowed to independently conduct genetic resource collection activities. They must establish cooperative relationships with local research institutions and share research results. Article 17 of the Convention further requires that international cooperative research agreements should clarify the ownership of data and the mechanism for benefit-sharing to ensure that the country providing the resources can equally share the research results.

The 2009 Guidelines for Human Biobanks and Genetic Research Databases issued by the

Organization for Economic Co-operation and Development (OECD)[5] refines the management requirements from an operational perspective. It stipulates that the establishment of biobanks must comply with the "principle of transparent governance," that is, disclosing the scope of sample collection, storage conditions, and usage rules. All samples must be anonymized or de-identified to avoid direct association between samples and personal identity information. The guidelines particularly emphasize that all data generated in international cooperative research must be filed with the regulatory authorities of the resource-providing country, and foreign research institutions can only use the data within the scope agreed in the agreement. Unauthorized use of data for other research purposes or transfer to third parties is prohibited.

In terms of the cross-border flow of genetic resources, Article 7 of UNESCO's Declaration on the Human Genome and Human Rights[6] stipulates that any international cooperation involving human genetic resources must first pass the ethical and security review of the country exporting the resources, and the research results generated should be prioritized for improving the public health level of the exporting country. The OECD guidelines[5] supplement the prohibition of "genetic resource exploitation," clearly stipulating that foreign institutions are not allowed to induce the country where the resources are located to give up control over genetic resources or obtain research rights beyond a reasonable scope by providing financial or technical support.

1.1.3 Infringement of Privacy and Data Security

The international regulatory framework imposes strict requirements of "full-process encryption and dynamic monitoring" on the privacy protection of biological data. It strictly prohibits the disclosure, tampering, or damage of personal information and biological data obtained through research, or the disclosure to third parties without permission. According to Article 32 of the GDPR, data processors must adopt technical measures such as encryption, hierarchical access rights, and regular security audits. For example, end-to-end encryption should be used to store genetic data, a "multi-factor authentication" mechanism should be set up to control data access rights, and security vulnerability detection should be carried out quarterly. In case of a data breach, the processor must report to the regulatory authority within 72 hours and promptly notify the affected participants. Those who fail to fulfill their security protection obligations may face a fine of up to 10 million euros.

The OECD Guidelines for Human Biobanks and Genetic Research[5] Databases further refine the requirements for data security management. They stipulate that biobanks must comply with the ISO/IEC 27001 information security standard and establish a "data access log" system to record the access time, operation content, and purpose of use of all personnel. The logs must be kept for at least 5 years to facilitate the tracing of illegal operations. The guidelines particularly emphasize that for anonymized data that can be traced back to personal identities through "re-identification technology" (such as matching genetic data with demographic information in public databases), additional "pseudonymization" processing is required. That is, random codes are used to replace personal identity identifiers, and the codes are stored separately from identity information.

In terms of data sharing and disclosure, Article 16 of the CIOMS 2016 Ethical Guidelines stipulates[3] that personal biological data shall not be disclosed to third parties (including other research institutions, commercial companies, or government departments) without the explicit authorization of participants. Even for anonymized data, an independent ethics committee must assess whether there is a "risk of re-identification." Article 6 of UNESCO's Declaration on the Human Genome and Human Rights emphasizes from a human rights perspective that every individual has "control rights" over their own genetic information, including the right to inquire

about, correct, or delete their genetic data, and no institution shall discriminate against individuals or restrict their basic rights based on genetic data.

The legal consequences of violating the above provisions include: at the international level, enterprises may be excluded from cross-border scientific research cooperation projects (for example, the EU's "Horizon" program will refuse to fund institutions with a record of data security violations); at the civil level, participants can file complaints with the United Nations Human Rights Committee in accordance with Article 12 of the Universal Declaration of Human Rights and Article 17 of the International Covenant on Civil and Political Rights, requiring the infringing institution to bear compensation liability; in case of large-scale data leakage, a joint investigation by international data security organizations may also be triggered. It is particularly worth noting that the 2021 Guidelines for Stem Cell Research and Clinical Translation issued by the International Society for Stem Cell Research (ISSCR)[7] incorporates data security into the "scientific integrity" evaluation system. It stipulates that researchers with a record of data leakage may have their research results rejected for publication by academic journals.

1.2 Ethical Red Lines: Protecting the Rights and Dignity of Respondents

1.2.1 Violations of the Principle of Informed Consent

International ethical guidelines clearly require that when conducting research involving personal biological information, researchers must strictly fulfill their obligation to inform and obtain valid consent. Article 27 of the Declaration of Helsinki stipulates that researchers should fully inform respondents of the purpose, content, potential risks, data usage, and retention period of the research in a prominent manner and in clear and understandable language, ensuring that respondents voluntarily give explicit consent on the basis of full information. For sensitive information such as gene sequences and medical records, separate written authorization must be obtained, and the "principle of minimization" must be followed, i.e., only collecting data necessary for the research. The Declaration also particularly emphasizes that respondents have the right to withdraw their consent at any time, and their access to routine medical services or other benefits shall not be affected by the withdrawal of consent. Researchers must provide convenient channels for withdrawal.

For special groups, Article 8 of the CIOMS 2016 Ethical Guidelines[3] requires that the collection of biological information from minors must obtain "dual consent" from their guardians, i.e., written consent from both the guardians and the minors themselves who have the ability to understand. For groups with limited cognitive abilities, simplified language and visual explanations should be used to ensure that they truly understand the research content and avoid "formal consent." If necessary, the ethics committee should appoint an independent witness to participate in the consent process. Article 5 of UNESCO's Declaration on the Human Genome and Human Rights further supplements that when indigenous peoples and other groups with special cultural backgrounds are involved, their cultural traditions and collective decision-making mechanisms should be respected, and additional permission from community leaders or elders' meetings may be required.

1.2.2 Endangering the Physical and Mental Safety of Respondents

Research content must not induce respondents to disclose information that may lead to discrimination or harm, such as genetic defects or medical histories of rare diseases. Article 12 of the CIOMS 2016 Ethical Guidelines[5] points out that such information is highly sensitive biological information, and its abuse may easily trigger discrimination in employment, education, insurance, and other fields. Researchers should avoid such issues in the research design stage, such

as refraining from asking questions that may expose privacy, such as "whether you carry cancer-susceptible genes" or "whether there is a family history of genetic diseases." If such information is necessary for the research, anonymization should be adopted, and it shall not be stored in association with personal identity information. Article 32 of the Declaration of Helsinki[2] further emphasizes that researchers should assess the potential impact of the research on the mental health of respondents. If the content may cause anxiety or psychological trauma (such as informing respondents of genetic testing results), free psychological counseling services must be provided.

1.2.3 Exploitation of Vulnerable Groups or Special Groups

It is strictly prohibited to treat poor people and marginalized groups as "low-cost research objects" or obtain data by taking advantage of their information asymmetry. Article 13 of the CIOMS 2016 Ethical Guidelines[5] stipulates that the processing of personal information of such groups must follow the principle of fairness, and the protection standards for their sensitive information shall not be lowered due to their vulnerable status, and shall be consistent with those for other groups. Researchers shall not induce vulnerable groups to participate in research by providing high remuneration to avoid "economic coercion." Article 23 of the Universal Declaration of Human Rights emphasizes from a human rights perspective that any group has the right to refuse to participate in research that may harm their own rights and interests, and shall not be discriminated against or treated unfavorably for refusing to participate.

For patient groups, priority should be given to protecting their medical rights and interests, and avoiding interference with normal treatment due to research. Article 35 of the Declaration of Helsinki[2] requires that such research must undergo strict evaluation by the ethics review committee, and it should be clearly stated that the research shall not affect the time and quality of the patients' access to formal treatment. If there is a conflict between treatment and research time, the patients' health shall be given priority, and patients shall be allowed to suspend or withdraw from the research. Researchers must maintain communication with the patients' attending doctors to keep abreast of the patients' treatment progress and avoid treatment delays caused by the research. The OECD Guidelines for Human Biobanks[5] and Genetic Research Databases further stipulate that research involving terminally ill patients should respect the dignity of their lives. It is not allowed to force data collection when patients are in the final stages of life, and the family members should be informed of the research content in advance to obtain their understanding and support.

1.3 Biosafety Red Lines

1.3.1 Involvement in Illegal Biological Activities or Endangering Biosafety

Research content must not involve the risk of abuse of synthetic biology or attempt to obtain data that may endanger public health and safety. The Convention on Biological Diversity (CBD) and its Cartagena Protocol[7] clearly stipulate that synthetic biology research must adhere to the bottom line of biosafety and prohibit the use of research as a pretext to evade supervision and obtain data that may pose public health risks. Article 10 of the Protocol requires that research involving living modified organisms (LMOs) must undergo biosafety review in advance to assess their potential risks to biodiversity and human health, and must be filed with the national biosafety authority of the country where the research is conducted.

1.3.2 Violations of Scientific Integrity

It is strictly prohibited to fabricate research data, conceal unfavorable results, or manipulate respondents' answers through misleading questions. scientific research activities must adhere to the principles of academic integrity and ethics. Data fabrication and tampering are serious scientific

misconduct. Researchers are responsible for the authenticity of data and must retain original research records for at least 5 years for verification. Article 20 of the CIOMS 2016 Ethical Guidelines supplements that the ethics committee shall supervise the entire research process, and the review process will verify the authenticity of data and the compliance of the research process to ensure the objectivity and fairness of the process and eliminate result distortion caused by human interference.

When publishing or applying research results, in accordance with the Personal Information Protection Law, personal identity information must be de-identified and anonymized to conceal identities. At the same time, technical protection measures should be taken to prevent the "de-anonymization" of personal information through correlation analysis and information matching.

2. Communication Skills

2.1 Clarifying Objectives and Audiences

Before launching scientific communication activities, accurately defining "what to communicate (What)" and "why to communicate (Why)" is the core prerequisite for avoiding aimless resource investment and building an effective communication system. The answers to these two questions directly determine the focus of the communication content and the measurability of the objectives[8]. In terms of "what to communicate," it is not sufficient to simply identify a broad scientific theme; instead, it is necessary to focus on specific and valuable content carriers (Sam Illingworth, 2017). If the objective is to "inspire high school students to engage in biological science research" (Why), the communication content should be precisely focused on "research breakthroughs, career paths, and industry development in biological science" (What), rather than superficially disseminating basic scientific knowledge. If the goal is to "increase public participation in cell therapy research," the communication content can focus on "the working mechanisms and application values of cell therapy projects that have completed clinical trials," rather than merely popularizing the principles of cell therapy.

At the same time, "why to communicate" needs to be further refined into actionable objective types: is it aimed at popularizing specific knowledge, changing cognitive attitudes, or promoting behavioral participation? Clarifying this dimension can make "what to communicate" more targeted and avoid disconnect between the communication content and the core objectives.

Furthermore, the audience of scientific communication is not a homogeneous group. There are significant differences in their cognitive levels, information needs, and interaction preferences. Communication strategies must be dynamically adjusted based on the characteristics of the audience. This is not only a practical response to "why to communicate" but also the key to ensuring that "what to communicate" truly reaches the target group[8]. Therefore, our team focused on this aspect in the pre-survey and divided the population into groups with different levels of scientific literacy for hierarchical education.

For groups with strong scientific literacy, they have sufficient knowledge reserves and tend to deepen their understanding through systematic information input such as academic papers and long videos. They have a high demand for the visualization of abstract concepts and need pictures to assist in logical reasoning. For them, we can use in-depth long articles with a combination of pictures and texts for popular science education, emphasizing the connection between technical principles and application scenarios to meet their needs for systematic knowledge input.

For groups with moderate scientific literacy, they have basic concepts but lack a knowledge network.

They need interactive feedback to strengthen their understanding and are relatively resistant to overly complex terminology. They hope to obtain accurate knowledge and are unwilling to accept "imprecise casual popular science," but they are easily discouraged by large sections of text. For them, we can adopt lightweight interactive forms, such as organizing debates, tea parties, and popular science fairs for communication and discussion, and provide picture-text manuals for assistance, using real-life scenarios as anchors to break down vague knowledge points.

For groups with weak scientific literacy, they rely on concrete experiences and may have difficulties in understanding abstract concepts. For them, we need to provide simple and highly interactive communication, supplemented by concrete descriptions for popular science. We can use immersive workshops to help them deeply understand concepts through hands-on operations, or use comics or picture books to explain scientific knowledge with anthropomorphic images.

It is also worth noting that in addition to hierarchical education, the public itself covers a wide range of groups, from students, teachers, and community residents to enterprise employees. Therefore, communication activities need to first identify the core audience. For example, in the communication of "soil ecological protection" for community residents, we can prioritize focusing on "local vegetable growers," discuss "the relationship between soil health and crop quality" through workshops, and design simple soil testing practical sessions. If multiple audience groups need to be covered, a "multi-level flexible strategy" should be adopted. For example, around the theme of "climate change and urban life," we can set up interactive booths at science festivals to attract ordinary citizens, carry out "campus carbon footprint measurement" activities in collaboration with schools, and organize in-depth readers through book clubs to discuss the scientific accuracy of relevant books, so that different groups can find suitable ways to participate[8].

More importantly, communication should not be a one-way "information indoctrination" but should incorporate a two-way dialogue mechanism. For example, when designing a panel debate, we can first communicate with the group to identify the scientific topics they care about, invite representatives to share life experiences as guests during the debate, and deepen interaction through open days at the laboratory after the debate. This model can not only make "what to communicate" more in line with the needs of the audience but also truly implement "why to communicate," ultimately maximizing the communication effect.

2.2 Communication Skills to Improve Reliability

Reliability refers to the consistency of results obtained when the same method is used to measure the same object repeatedly. In other words, reliability refers to the reliability of measurement data. In our scientific research, we should try to adopt the following methods to improve the reliability of the information collected after communication.

2.2.1 Aligning Project Features with Interviewees' Interests in Communication

A meta-analysis study published in 2023 (with extensions related to Nye et al.) verified through 92 studies and 1858 sets of data that the predictive power of interest consistency on information reliability (correlation coefficient 0.32) is significantly higher than that of simple interest scores (0.16). This is because when the project content matches the respondents' interests, their cognitive engagement increases, enabling them to recall information more stably and express their true attitudes, thereby reducing answer biases caused by perfunctory responses or misunderstandings and minimizing result fluctuations during repeated measurements.

2.2.2 Clearly Defining Concepts to Avoid Ambiguity

The ambiguity in the definition of concepts directly leads to systematic measurement errors, which

is one of the core factors restricting reliability. any unclearly defined concept will become a flexible space for respondents' cognition, leading to different individuals forming different understandings based on their own experiences, and ultimately significantly reducing the consistency of results in repeated measurements. The errors caused by such cognitive differences are essentially random errors, and the core value of reliability lies in achieving result stability by controlling such errors [9].

A research team on health from the University of Adelaide in Australia found through the analysis of 12 sets of cross-border health survey data that when core concepts are not clearly defined, the coefficient of variation of respondents' answers averages 0.43, which is 2.4 times that of the group with clear concepts. This high variation stems from individual differences in the "concept understanding threshold," and such cognitive differences may directly lead to data failure to reflect the true characteristics of behavior.

From the perspective of measurement theory, undefined concepts will reduce the proportion of "true score variation" in the total variation. According to the classical measurement model $X=T+E$ (where X is the observed score, T is the true score, and E is the error score), when there is ambiguity in a concept, the error score E will include a large number of "understanding deviation items," leading to a significant decrease in the reliability coefficient. A 2024 study on SpringerLink pointed out that in the development of psychological scales, if 30% of the questions under a certain dimension have ambiguous concepts, their alpha coefficient will drop from 0.82 to below 0.65, falling below the basic research reliability acceptance threshold (0.70). When asking questions, we should use language that is familiar to respondents and free of ambiguity, and provide simple explanations or specific examples for professional terms or abstract concepts. This requires the questions to be clear and rigorous.

2.2.3 Structured Follow-up to Verify Consistency

Asking the same core information in different ways at different times, while avoiding mechanical repetition, can effectively verify whether the interviewees' answers have high credibility. Through standardized dynamic verification, this process fills the gap of answer contradictions that cannot be identified by "static questioning," and its core value lies in reducing random errors caused by "memory bias" and "ambiguous expression." Cognitive interview theory provides methodological support for structured follow-up. The four principles of cognitive interviews proposed by Fisher and Geiselman[15] emphasize that structured follow-up should be designed around "core information - detailed supplement - logical verification" rather than random questioning. This process can effectively reduce the reliability loss caused by "generalized answers".

2.2.4 Immediate Clarification and Confirmation

The core value of immediate clarification and confirmation is to block the error transmission of ambiguous answers, convert "potential ambiguity" into "clear information" through real-time intervention, and avoid the accumulation of errors in subsequent measurements. A clinical evaluation study published on ResearchGate in 2023 [10]pointed out that "when ambiguous answers persist for more than 30 seconds, the accuracy of the additional information provided by respondents will decrease by 42%, because the ambiguity of the initial expression will interfere with their memory retrieval process," which confirms the necessity of immediate intervention.

From the perspective of error control theory, immediate clarification is a key link in "closed-loop error control." The control of random errors requires the three-step linkage of "real-time monitoring - immediate correction - feedback verification," and ambiguous answers are exactly the "explicit

signals" of random errors. For example, when a respondent answers "I exercise several times a week," if the ambiguous expression "several times" is not clarified immediately, during subsequent retests, the respondent's definition of "several times" may change from "3 times" to "5 times," directly reducing the test-retest reliability. In addition, although the belief correction study focuses on the correction of misinformation, its core findings can be extended to the research scenario: immediate intervention can prevent respondents from forming "ambiguous cognitive anchors," while delayed clarification will solidify ambiguous answers into "default memories," resulting in a threefold increase in subsequent correction costs.

From the perspective of cognitive psychology, immediate clarification conforms to the law of "limited working memory capacity." When respondents give ambiguous answers, their working memory still retains relevant details, and immediate clarification can directly activate these details. If clarification is delayed, the details in the working memory will be covered by new information, and respondents need to rely on "reconstructed memory" to answer, leading to an increase in error rates. This is highly consistent with Babbie's view in Social Research Methods that "reliability depends on the immediacy of information retrieval."

2.2.5 Maintaining Neutrality and Reducing Suggestiveness

Avoid implying expected answers or value judgments in questions and use neutral wording. The core value of maintaining neutrality is to block the implantation of systematic errors. Suggestive questions, by implying expected answers or value judgments, force respondents to deviate from their true cognition, leading to a continuous expansion of the deviation between the observed score and the true score. Babbie clearly pointed out in Social Research Methods (2022)[11] that "any question with emotional tendency or preset position essentially transforms the researcher's subjective judgment into a 'cognitive anchor,' forcing respondents to adjust their answers to cater to this anchor. This deviation is systematic rather than random and will directly reduce the test-retest reliability and inter-rater reliability." This view is highly consistent with the classical measurement model $X=T+E$. The errors caused by suggestive questions are "uncontrollable systematic errors" that cannot be eliminated by increasing the sample size.

From the perspective of social science methodology, neutrality is the specific embodiment of the "value neutrality" principle in the research scenario. When respondents perceive the interviewer's expectations, they will choose answers that are in line with social norms or implied by the interviewer.

At the same time, some questions are highly suggestive, as they limit the scope of answers through preset premises. A study on elderly health on ResearchGate (2003)[12] found that questions such as "To what extent do you still have difficulty exercising?" already imply the premise that "the respondent has difficulty exercising," leading 28% of respondents with no difficulty to be forced to choose "slight difficulty," while the error rate of the neutral question "Do you have difficulty exercising?" is only 7%.

Cognitive psychology further explains that suggestive questions use the "anchoring effect" to interfere with the retrieval of working memory. When questions contain emotional words such as "beneficial" or "harmful," the amygdala of respondents will first activate emotional responses, inhibiting the retrieval of rational memory, leading to answers based on "emotional cues" rather than "factual recall" [13]. This emotional interference has a particularly significant impact on research related to subjective attitudes.

2.2.6 Building a Good Relationship and Encouraging Candor

The core value of building a good relationship is to establish cognitive security. By reducing the respondents' defensive psychology and concerns, it minimizes random errors and concealment biases caused by emotional fluctuations or privacy concerns. The self-disclosure theory in the field of psychology [17] provides core support for this. In *The Transparent Self*, Jourard clearly pointed out that "the degree of disclosure of an individual's true information is positively correlated with the level of interpersonal trust. When the environment has the characteristics of 'non-judgment' and 'confidentiality,' the depth and accuracy of self-disclosure will be significantly improved."

From the perspective of social exchange theory, the research process is essentially a reciprocal exchange between "researchers and respondents": researchers provide a safe atmosphere, and respondents repay with true information. When researchers fail to establish a trusting relationship, respondents will avoid risks through "superficial answers" and "information concealment," leading to "politeness bias" in the data. This bias is a "situational random error" that fluctuates with the quality of the relationship and needs to be systematically controlled by actively building a good relationship.

Cognitive psychology further explains that a good relationship can inhibit the stress response of the amygdala. When respondents perceive active listening and empathy, the rational decision-making area of the prefrontal cortex of the brain is more active, reducing memory retrieval biases caused by tension. Gubrium and Holstein supplemented in *Interviewing: The Art of Science* that "'rapport' in interviews is not simply emotional resonance, but a 'psychological safety contract' built through non-verbal signals such as eye contact, nodding, and verbal feedback. This contract can reduce the fluctuation range of respondents' answers by more than 35%."

2.3 Communication Skills to Improve Validity (Accuracy)

As the core indicator of information authenticity, validity requires the communication process to go beyond superficial responses and capture in-depth data that reflects the essence of the research.

2.3.1 In-depth Follow-up and the "Onion Peeling" Technique

Continuously use the 5W1H (Who, What, When, Where, Why, How) framework and "specific" questions to go beyond surface answers and reach the core details, motivations, and backgrounds.

2.3.2 Focusing on Behaviors and Specific Examples

Avoid only asking about opinions or attitudes (which are susceptible to social desirability bias), and focus on asking about actual behaviors, specific events, and observable results.

2.3.3 Using Non-verbal Information for Insight and Follow-up

Keenly observe non-verbal signals of respondents, such as facial expressions, body language, tone of voice, pauses, and evasions. When inconsistencies between language and non-verbal cues or potential emotions are detected, follow up gently but directly.

2.3.4 Challenging Assumptions and Exploring Contradictory Evidence

Proactively ask about possibilities that contradict the respondents' views or have not been mentioned to test the comprehensiveness and depth of their views.

2.3.5 Contextualized Questioning

Place questions in specific contexts to help respondents recall details, reconstruct real scenarios, and reduce general biases.

2.3.6 Distinguishing Between Facts and Opinions

Technique: When respondents mix facts and opinions in their statements, gently ask them to make a distinction.

2.4 Core Communication Principles Throughout the Process

2.4.1 Active Listening

Concentrate fully and show focus through eye contact, nodding, and brief responses (such as "Hmm," "I see," "Please continue"). Special attention should be paid to the following four aspects of the interviewee's content:

Listening to the content + listening to the emotions + listening to the logic + listening to the unspoken meaning

These four types of "listening" do not occur in sequence but simultaneously and mutually confirm each other. An excellent interviewer is like a high-precision sensor, receiving these four signals at the same time and comprehensively processing them.

① Listening to the Content

What it is:

This is the most basic level, which involves listening to the surface information in the other person's words, such as facts, data, events, and opinions. Most of the notes we need to take come from this.

How to listen:

- Capture key words: Focus on core nouns, verbs, and adjectives.
- Distinguish between facts and opinions: Differentiate between "what happened" (facts) and "how he views this matter" (opinions).
- Organize the information structure: How does the other person organize their language? Is it in chronological order, order of importance, or logical argumentation?

Possible problem signals:

- Vagueness: Words like "more or less," "it seems," "some people"—follow-up questions are needed to make them specific.
- Generalization: Words like "always," "never"—follow-up questions are needed to ask for counterexamples.
- Missing information: Skipping key links and glossing over a certain part.

How to respond:

- Ask for details: "When you mentioned 'some people,' who exactly do you mean?"
- Request examples: "You said there was a 'communication breakdown.' Can you give a recent example?"
- Clarify and confirm: "So what you mean is that first A happened, which then led to B. Is that correct?"

② Listening to the Emotions

What it is:

This involves listening to the emotional overtones and emotional states conveyed in the language. Emotions are the "amplifiers" or "filters" of information and can reveal the respondents' true attitudes and level of engagement with the event.

How to listen:

- Tone and intonation: Is the voice trembling? Is the tone high or low? Is the speech rate fast or slow? (For example, the speech rate speeds up when excited, and slows down with pauses when sad.)
- Emotional connotations of words: Are positive words (such as "great," "exciting") or negative words (such as "terrible," "disappointing," "exhausting") used?

Non-verbal signals (very important!):

- Facial expressions: Smiling, frowning, evasive eyes, pouting.

- Body language: Crossing arms (defensive), leaning forward (interested), fidgeting (nervous and anxious), holding the forehead (frustrated).

Possible problem signals:

- Emotions do not match the content: Using a flat tone to talk about something that should theoretically be exciting (there may be hidden resentment or dishonesty).
- Sudden changes in emotions: Suddenly becoming angry or evasive when talking about a certain topic.

How to respond:

- Point out and verify (empathic follow-up): "It seems to me that you feel a little disappointed about this matter?" or "I noticed you smiled when you mentioned this part. What made you find it interesting?"
- Provide space: If the other person is emotionally excited, you can pause briefly and say, "It's okay, take your time."
- Acknowledge emotions: "I understand that this can indeed be very stressful."

③ Listening to the Logic

What it is:

This involves listening to the internal connections, causal reasoning, and argumentation processes in the information. It involves judging whether the other person's narration is self-consistent and whether there are loopholes or contradictions.

How to listen:

- Look for the causal chain: Does he clearly explain how A leads to B? Is this causal relationship valid?

Identify logical loopholes:

- Leapfrog reasoning: Missing intermediate links and jumping directly from A to C.
- Circular reasoning: Using the conclusion itself to prove the conclusion.
- Contradictions: What is being said now is inconsistent with what was said 10 minutes ago.
- Evaluate evidence: Is his view based on specific examples or generalizations?

Possible problem signals:

- Invalid "because... so..." reasoning: "Because I am the project leader, my decisions are always correct." (Authority does not equal correctness.)
- Logical breaks: "Our team worked very hard, so the project failed." (There is a missing link between hard work and failure, and the real reason is hidden.)

How to respond:

- Challenge assumptions (gently): "You just mentioned that your decisions are always correct. Have you ever encountered an exception? How did you handle it then?"
- Fill in logical gaps: "You said the team worked hard but the project failed. What else happened between these two events?"
- Ask for an explanation of the reasoning process: "How did you reach this conclusion? Can you share your thinking process?"

④ Listening to the Unspoken Meaning

What it is:

This is the highest level, which involves listening to silence, evasion, deliberate omission, hints, and assumptions. The true meaning is often hidden in the unspoken words.

How to listen:

- Pay attention to evaded topics: You ask a key question, but the other person avoids it or glosses over it lightly.
- Be alert to "official jargon" and clichés: Is the other person answering with standard answers or public relations language instead of their true personal feelings?
- Identify "taboo areas": Which topics make the other person immediately become cautious or silent?
- Focus on "should" and "must": Behind these words, there are often unspoken rules, pressures, or expectations. (For example, "I have to do this" may imply "otherwise I will be punished.")

Possible problem signals:

- Silence or overly long pauses: Hesitating when answering a simple question may indicate that the person is editing their words or hiding something.
- Changing the subject: "The question you asked is very interesting, but what's more important is..."
- Minimalist answers: Using responses like "it's okay" or "nothing special" to talk about important events.

How to respond:

- Point out the silence (carefully): "I notice that this question may be a bit difficult to answer, or maybe I didn't ask it in the right way?"
- Follow up on evasions: "You just mentioned A, but I am actually also interested in B. Can you tell me more about B?"
- Interpret hints: "When you said 'some things are not up to me to decide,' does this mean you encountered some external resistance in the decision-making process?"

2.4.2 Non-judgmental Attitude

In an interview scenario, a non-judgmental attitude is the key to building trust and obtaining true information. Its core is to avoid triggering the interviewee's defensive psychology due to subjective evaluations through objective expressions and empathetic listening. The following is a specific framework of techniques and practical key points:

① Questioning Stage: Using "Neutral Design" Instead of "Guided Judgment"

Questioning is the starting point of an interview. A non-judgmental attitude requires that the questions themselves do not have a tendency or preset conclusions, allowing the interviewee to express their true views freely.

- Distinguish between "observation" and "judgment": Use specific factual descriptions instead of subjective evaluations. For example, ask "You have been late 3 times in the past month. Can you tell me the reason?" instead of "You are always irresponsible and often late?" The former is an objective observation, while the latter is a judgment. The former is more likely to make the interviewee let down their guard.
- Avoid "suggestive words": Refrain from using sentence patterns with implications such as "isn't it" or "don't you think." For example, ask "What is your experience of using this product?" instead of "Don't you think this product is particularly easy to use?" Neutral questions can guide the interviewee to give more true feedback.
- Use "open-ended questions" instead of "closed-ended questions": Open-ended questions (such as "Can you talk about your understanding of this policy?") provide the interviewee with more room for expression, while closed-ended questions (such as "Do you support

this policy?") tend to limit their thinking and even trigger confrontation.

② Response Stage: Using "Facts + Feelings" Instead of "Accusatory Expressions"

When it is necessary to respond to the interviewee's views, a non-judgmental attitude requires expressing feelings using "I" statements instead of accusing the other person.

- "Fact + feeling + need" structure: For example, when the interviewee refuses to answer a certain question, say "I notice that you seem hesitant about this question (fact). I am a little worried that my question may have made you uncomfortable (feeling). If it's convenient, can you tell me which aspects you are more willing to talk about? (need)" instead of "Why won't you answer my question?" The former is a cooperative expression, while the latter is an accusation. The former is more likely to make the interviewee cooperate.
- Avoid "absolute words": Do not use extreme words such as "never," "always," or "absolutely," as these words will make the interviewee feel denied. For example, say "Your report this time does not mention user research data" instead of "You never do user research." The former points out a specific problem, while the latter is a judgment. The former is more likely to trigger a discussion on solving the problem.

③ Conflict Handling Stage: Using "Repetition + Clarification" Instead of "Argument"

When there is a disagreement with the interviewee, a non-judgmental attitude requires first understanding the other person's views before expressing one's own thoughts.

- Repeat the other person's views for verification: For example, when the interviewee says "I think this plan is completely unworkable," first respond "So you mean there are difficulties in the implementation of this plan, right?" Confirm the other person's views to make them feel understood, and then continue "I want to add that the XX link of this plan is actually designed to solve the XX problem. What do you think?" Such a conversation is a communication, not an argument.

2.5 Evaluation and Iteration: Continuously Optimizing Communication

In iGEM Education, the evaluation and iteration system after dialogue and communication is the core link connecting "communication behavior" and "the implementation of educational objectives." It transforms the fragmented information collected during the active listening stage into actionable improvement plans, and ultimately realizes the closed loop of "precision in educational effects, dynamic adaptation to audience needs, and continuous improvement of project value." This is not only about "correcting problems" but also about upgrading iGEM Education from "one-time communication" to a "sustainable and optimized educational ecosystem." Such evaluation and iteration need to cover three levels: "output - outcome - impact." Its core is to comprehensively verify the "completion degree, effectiveness, and long-term value" of scientific communication activities through progressive measurement of "output - outcome - impact," avoiding focusing only on superficial indicators such as "number of participants." Each level needs to design targeted evaluation methods based on the type of activity and rely on specific cases to ensure practicality (Suzanne Spicer, 2017).

Output

Output refers to the "basic achievements" of scientific communication activities. It is necessary to quantify the "activity implementation status" and "audience reach status," but we should avoid "quantity-only theory" and supplement the dimensions of "audience quality" and "resource input efficiency," such as the number of participants, the number of activities, the ratio of resource input to output, audience matching degree, and completeness of content delivery (Suzanne Spicer, 2017).

Outcome

Outcome refers to the direct effect of scientific communication activities, focusing on the immediate or short-term changes in the audience's "knowledge, attitudes, and skills." It is necessary to use tools such as "before-and-after comparison" and "in-depth interviews" to avoid subjective judgments, such as the improvement of the audience's knowledge and changes in attitudes. "Before-and-after tests" or "cognitive mapping" tools are often used, and "quick questions" are used to count the correct rate. For the evaluation of adults, a "knowledge scale" can be used to judge changes through the difference between pre-test and post-test scores (Suzanne Spicer, 2017).

Impact

Impact refers to the "in-depth value" of scientific communication activities, focusing on the long-term behavioral changes of the audience or the indirect impact on society. It is necessary to break through the limitations of "short-term evaluation" and rely on "long-term tracking" and "third-party feedback," such as long-term behavioral changes, which can be tracked for a long time through regular follow-ups and community observations. However, the evaluation of impact needs to clarify the causal relationship and avoid attributing natural changes to the activities (Suzanne Spicer, 2017).

3. Scientific Design of Synthetic Biology Questionnaires Based on the Principles of Reliability and Validity Assurance and Ethical Standards

In the social research scenario of synthetic biology, questionnaires, as the core data collection tool, their design quality directly determines the scientificity and ethical compliance of the research conclusions. The scientific design of questionnaires should take the optimization of reliability and validity as the core goal and consolidating ethical boundaries as the fundamental bottom line. It should achieve in-depth integration through psychological theories and methods, so as to form a "three-heart" closed-loop system of "concern for interviewers, comfort for interviewees, and confidence in research data," and provide high-quality data support for social cognition research in the field of synthetic biology.

3.1 Systematic Design for Reliability and Validity Assurance

Reliability and validity are the core indicators to measure the quality of questionnaire data. They need to run through the entire process of questionnaire design, pre-research, data collection, and analysis. With the guidance of psychological theories and the test of practical methods, the response bias should be minimized and the data reliability should be improved.

3.1.1 Audience Stratification and Cognitive Matching

According to cognitive psychology theory, there are differences in the cognitive structure and information processing methods of individuals. The field of synthetic biology is highly professional, and the threshold for understanding its concepts shows significant differences depending on the audience's knowledge reserves, professional background, and life experience. If the cognitive differences are ignored and only a unified expression is adopted, it is easy to lead to response errors and weaken the data validity.

① Hierarchical Transformation of Concept Expression

For different audience groups, we need to transform the core concepts of synthetic biology from academic to popular expressions. For professional groups, academic expressions should be used to ensure that the questions match the professional cognitive system, directly focus on the key points of industry research, and obtain in-depth data. For the public, daily and analogous descriptions should be used to transform professional terms into daily cognitive concepts, avoid understanding obstacles, and reduce cognitive load.

② Optimization Based on the MRPs Phenomenon

(Figure 1: Data survey on the MRPs phenomenon conducted by Craig et al.)

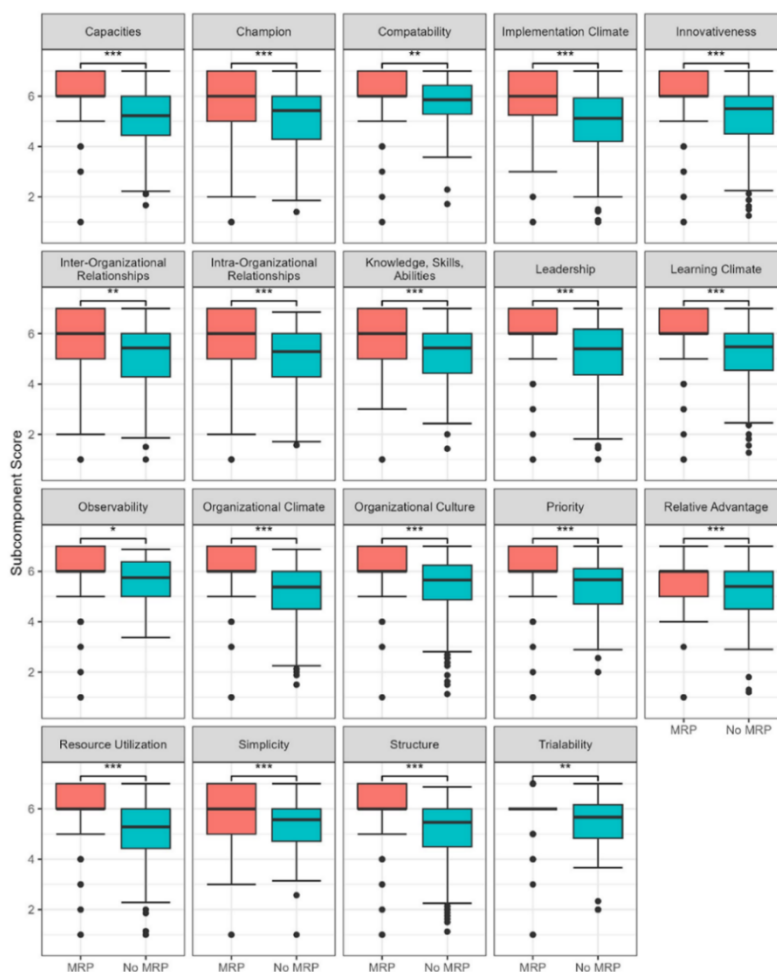


Figure 1: Within each subcomponent, respondents were classified as exhibiting a Monotonic Response Pattern (MRP) or not. The distribution of subcomponent scores for those with and without MRPs for each subcomponent are compared. Test: T-Test; (** = 0.01; *** = 0.001; * = 0.05)

Through T-test analysis, Craig et al. found that there are significant differences in the monotonic response patterns (MRPs) among respondents with different backgrounds in each sub-dimension of the questionnaire. Some groups tend to choose the same option for similar questions instead of answering based on the core logic of the questions. This phenomenon reminds us that we need to optimize the question expression and option settings according to the audience differences of each sub-dimension:

- For sub-dimensions that are prone to MRPs, such as "ethical attitude assessment," the specificity of the question context should be increased, and the inertia of homogeneous

responses should be broken through specific contexts. For example, "Regarding embryo gene editing technology, under what conditions do you think its application can be allowed: A. Treating genetic diseases B. Preventing common diseases C. Optimizing physiological characteristics D. Not allowed in any case"

- For non-MRP sub-dimensions, the expression can be simplified appropriately to improve the response efficiency.

3.1.2 Questionnaire Length Control

The length of the questionnaire and the response time directly affect the psychological state of the respondents. Too many questions or high complexity will cause the cognitive load to exceed the threshold, which may lead to careless checking, fixed option cycling, and false answers, significantly reducing the data reliability.

① Prioritizing Core Questions

Sort the questions according to the two dimensions of "information importance + data contribution," and place the key core variables in the first 50% of the questionnaire, with secondary variables placed later.

② Response Time Threshold

The time required to complete a single questionnaire should be controlled within 15 minutes as much as possible. The response time can be tested through pre-research, and redundant questions can be streamlined and merged to ensure that the overall process load is within the psychological fatigue threshold.

3.1.3 Logical Progression of Questions

Individuals' cognition of things follows the psychological path of "from simple to complex, from basic to in-depth." If the questionnaire questions violate this path, it is easy to cause cognitive gaps among respondents, trigger resistance or logical fallacies, and reduce the data reliability and validity. Especially for sensitive issues related to technical risks and ethics, a progressive question logic should be used as a buffer to reduce the respondents' defensive psychology. Trust should be established through neutral questions before transitioning to sensitive topics.

3.1.4 Scientific Inspection of Questions

The scientificity of question expression and option settings is the key to ensuring reliability and validity. In practice, we can use a variety of methods to reduce response bias and improve the matching degree between data and true attitudes.

① Question Consistency Inspection

Use synonymous transformed expressions for core attitude questions to test the consistency of responses. For example:

Positive expression: "The development of synthetic biology technology has more advantages than disadvantages"

Reverse expression: "The risks of synthetic biology technology outweigh the benefits"

If there is a contradiction between the respondents' answers to the two types of expressions, the data should be marked as suspicious, and further testing should be conducted in combination with other questions.

② Avoiding Social Desirability Bias

Social desirability in questionnaires refers to the tendency of individuals to choose answers that conform to social norms rather than their true personal attitudes. It can be weakened in the following ways:

- Changing the subject of the question: Change "What do you think" to "What do most people around you think" to reduce the pressure of self-expression. Obtain true attitudes indirectly through the third-person perspective.
- Pre-statement: Mark at the beginning of the questionnaire or before the sensitive question module: "This survey has no correct/incorrect answers. The options only reflect different view tendencies. Your true thoughts are crucial to the research" to weaken the convergence psychology.

③ Flexibility of Options

In actual surveys, we should avoid absolute options: expand the single "agree/disagree" option to a five-point Likert scale of "strongly agree → somewhat agree → neutral → somewhat disagree → strongly disagree," or add intermediate subjective options such as "agree in some cases."

3.1.5 Pre-research

Pre-research is the "error-testing link" of formal research. It verifies the feasibility of the questionnaire design and corrects potential problems through small-sample testing. The core goals of pre-research are optimization and verification. The average response time and hesitation times of the pre-research respondents can be recorded to optimize the question order or expression. The acceptance of the privacy policy and sensitive questions by the respondents can be used to adjust the privacy statement or the way of asking sensitive questions. Before the formal research, it is necessary to ensure that the questionnaire conforms to academic standards and is in line with the research objectives.

3.2 Comprehensive Consolidation of Ethical Standards

The ethical standards of questionnaire research should take "protection of respondents' rights and interests" as the core, and build a comprehensive and multi-level ethical standard system based on psychological theories to ensure that the research activities comply with legal norms and conform to academic ethics.

3.2.1 Prioritizing a Sense of Security

Maslow's Hierarchy of Needs Theory points out that "safety needs" are a prerequisite for individuals to express themselves truthfully. Surveys on synthetic biology involve sensitive topics; without establishing a psychological safety zone, respondents tend to conceal their true attitudes, leading to data distortion. To address this, we must clearly state safety commitments at the beginning of the questionnaire to safeguard respondents' rights.

Specific Content of Safety Commitments

- **Transparent Communication of Research Objectives:**

"This survey focuses on public perceptions and ethical attitudes toward synthetic biology technology, aiming to provide academic references for disciplinary development planning and science popularization policies. Data will only be used for non-commercial research purposes and will not involve any commercial cooperation or collection of personal information."

- **De-linking of Personal Information:**

"All response data will only be used for analyzing group trends and will not be linked to your personal identifiers (such as name or ID number). The final research results will only present aggregated conclusions."

- **Neutrality in Attitude Evaluation:**

"Regarding your views on ethical issues related to synthetic biology, the research team will only record the tendency of your opinions. No judgments of 'right' or 'wrong' will be made, nor will your

views be tied to your personal characteristics."

- **Targeted Protection for Vulnerable Groups:**

For high-concern groups (e.g., patients, industry practitioners), personalized commitments should be added to informed consent forms. For example: "If you are a gene technology practitioner, your survey responses will not be shared with your employer, nor will they affect your professional evaluation." This helps further alleviate their defensive mindsets.

3.2.2 Protection of Autonomy and Privacy

Deci & Ryan's Self-Determination Theory argues that when an individual's needs for autonomy, competence, and relatedness are met, their willingness to participate and level of cooperation increase significantly. Questionnaire design must strengthen respondents' right to choose, right to withdraw, and technical safeguards for privacy—ensuring respondents retain control throughout the process. A prominent note should be included at the start of the questionnaire:

"This survey is voluntary. The entire completion process is fully anonymous, and you may close the page to terminate participation at any time without providing a reason."

3.2.3 Feedback on Participation Value

Blau et al.'s Social Exchange Theory states that individuals follow a "cost-benefit trade-off" principle in social interactions. When respondents perceive that their "participation benefits" (e.g., gaining knowledge, driving positive change) outweigh "participation costs" (e.g., time, privacy risks), their trust and cooperation will improve significantly. Feedback on participation value can be provided either at the end of the questionnaire or within 15 days of survey completion, via channels approved by the respondent (e.g., email, SMS). An example of such feedback:

"A total of 2,000 respondents participated in this survey. Your views align with 68% of participants, and together, these perspectives have raised awareness of 'technology risk management and control'." This helps respondents feel a sense of collective value.

3.2.4 Post-Survey Privacy Reinforcement

Post-survey privacy feedback is the "final critical step" in ethical standards. Multiple measures must be taken to form a closed loop for privacy protection, further strengthening respondents' trust. Specific practices include:

- 1) **Compliant Presentation of Aggregated Data:**

Feedback must focus strictly on "group trends" and completely exclude any individual-specific information.

- 2) **Reiteration of Privacy Measures:**

Provide respondents with detailed explanations of how privacy protection has been implemented; technical specifics can help enhance trust. For example: "All raw data has been stored in encrypted form as promised, and no data leaks or unauthorized use have occurred to date."

- 3) **Commitment to Data Destruction:**

Clarify the data lifecycle to eliminate respondents' concerns about long-term information retention risks. For example: "The raw data from this survey will be deleted under the supervision of designated personnel within 3 months of the finalization of the research report. Only aggregated data will be retained for future academic reference."

In the design of synthetic biology questionnaires, reliability and validity are not independent of ethical standards—instead, they form a mutually integrated and synergistic relationship:

- Ethical standards lay the foundation for reliability and validity: Robust privacy protection and a well-established psychological safety zone reduce respondents' defensive attitudes,

thereby improving data reliability and validity.

- Optimizing reliability and validity supports ethical standards: Enhancing the scientific rigor of questions and refining logical structure reduces respondents' resistance caused by confusion or cumbersome procedures, increasing their recognition of the survey.

4.Theory and Strategies for In-depth Communication with Different Age Groups from the Perspective of Enhancing Reliability and Validity

In social research, obtaining information with high reliability and validity has always been the core prerequisite for achieving research objectives and practical outcomes. Due to differences in upbringing, social experience, and access to technology, different age groups have developed unique communication preferences, psychological mechanisms, and information-processing patterns. Therefore, developing targeted communication strategies is not only an optimization at the methodological level but also a respect for and response to group differences—this embodies the core value of iGEM: respect.

4.1Under 18 Years Old

4.1.1 Age Group Characteristics

Individuals in this group are in the stage of accumulating cognitive and social experience, with limited scope for social interaction and activities. Their social networks center on family and school, with few independent social scenarios, leading to concentrated activity spaces. As "digital natives," their cognitive habits and information-acquisition methods are deeply influenced by digital technology; however, their use of electronic devices is subject to dual regulation by family supervision and school management, leaving them with limited autonomy. They have a strong need for group belonging and emotional recognition, while their attention spans are short and easily distracted by the external environment. Additionally, their awareness of safety precautions and personal privacy protection is still in its infancy, with a vague understanding of "privacy boundaries," making them prone to disclosing personal or family privacy during communication.

4.1.2 Relevant Research

According to the Actor-Network Theory (ANT) proposed by Bruno Latour, Michel Callon, John Law, and others, scientific communication must fully consider the connections formed between actors [1]. The connections among individuals under 18 differ from those among adults, requiring additional consideration of this group's links with family, school, and community.

4.1.3 Corresponding Strategies

- 1) **Survey Methods:** Prioritize offline surveys, primarily conducted through schools and communities, while strictly adhering to the principles of informed consent and voluntary participation—no forced time commitment is allowed. For online surveys, leverage algorithmic recommendations for precise targeting to improve reliability and validity.
- 2) **Communication Style:** Demonstrate empathy and patience, with a focus on providing emotional support. Build trust through ice-breaking activities in the early stages; continuously monitor the respondent's emotional state during communication to ensure

interactions occur when they are in a positive mood. Incentives may be provided if necessary.

- 3) **Tool Design:** If using questionnaires, the interface should align with the age group's preferences, and questions should be simple and easy to understand, avoiding overly abstract concepts or jargon. If conducting interviews, repeatedly adjust questions based on the respondent's feedback to facilitate comprehension. A study on relevant practitioners found that they hold biases against "adjusting questions based on audience feedback," viewing it as unethical "manipulation" [2], while overlooking the critical role of respondent feedback in research.
- 4) **Privacy Protection:** When survey questions involve private content, strictly comply with local laws and regulations, and obtain consent from both the respondent and their guardian.

4.2 18–25 Years Old

4.2.1 Age Group Characteristics

The core trait of this group is "digital nativity": born into an environment fully permeated by digital technology, digital tools serve not only as auxiliary means in their lives but also as core carriers for shaping their cognitive and social patterns (Prensky, 2001). They prefer online social interaction, value personalization and authenticity, have high sensitivity to data privacy (especially social media data), exhibit fragmented attention spans, and favor relaxed, informal communication.

4.2.2 Relevant Research

A study on virtual community participation by Offiong et al. (2023) showed that this age group, as "digital natives," is highly active in online collaboration; however, issues such as device accessibility (e.g., providing dedicated iPads) and privacy anxiety need to be addressed. At the psychological level, personalization and authenticity are core needs. Erikson's Identity Development Theory notes that the key task of adolescence is establishing ego identity, leading this group to have a stronger desire for "being treated uniquely" and "sincere communication and connection."

4.2.3 Corresponding Strategies

- 1) **Channel Selection:** Leverage online channels as the core communication medium, in line with their "digital nativity" trait. Provide technical support (e.g., free WiFi hotspots, dedicated mobile devices) to eliminate interference from the "digital divide" in information access, ensuring equal participation across groups of different socioeconomic statuses.
- 2) **Language Style:** Use direct, sincere, transparent, and informal language to align with their psychological need for "authenticity." The "homophily effect" theory suggests that information reception efficiency significantly improves when the communicator's language style matches the recipient's self-perception.
- 3) **Privacy Assurance:** Provide clear and specific explanations of the privacy data protection system, and explicitly define the boundaries of data use.
- 4) **Value Feedback:** Highlight how their participation contributes to project design or advances social issues they care about, to activate their "sense of social engagement." This aligns with the "relational needs" of Social Exchange Theory (SET)—individuals' intrinsic motivation increases significantly when they perceive their actions can foster social connections.
- 5) **Interface Design:** For online questionnaires, adopt a "youthful" interface that is user-friendly, concise, and engaging. Incorporate game/anime elements (e.g., progress bars,

achievement systems for questionnaire completion) to boost participation interest.

- 6) **Question Design:** Use more scenario simulations or hypothetical questions. Such questions reduce defensive attitudes: due to their "depersonalized" nature, hypothetical scenarios place participants in virtual contexts. The "role effect" indicates that when individuals are in fictional scenarios, their self-monitoring decreases, and the authenticity of information disclosure improves.

4.3 26–55 Years Old

4.3.1 Age Group Characteristics

Spanning "Millennials" and "Generation X," the core trait of this age group is "digital transitionality": they experienced the shift from a non-digital to a digital society during their growth, leading to a distinct "balanced tendency" in their communication behavior. They value work-life balance, are more sensitive to information related to finances, career development, and family relationships, and are accustomed to diverse communication methods.

4.3.2 Relevant Research

A study on Millennials in the workplace (Seitenbach, 2019) noted that this group ranks work flexibility and managerial empathy as key factors for mental health. A study on virtual collaboration (Offiong et al., 2023) emphasized the need to adjust meeting times to accommodate their multitasking schedules.

4.3.3 Strategies

- 1) **Respondent-Led Channel Selection:** Address their "diverse adaptability" by offering options such as online meetings and offline interviews. Explain the advantages of each option and allow respondents to choose based on their own circumstances.
- 2) **Communication Style:** Adopt a professional yet friendly tone, with an emphasis on communication efficiency. Professionalism is reflected in clear explanations of research background and logical question design; friendliness is demonstrated through positive responses to their opinions. Social Exchange Theory (SET) posits that communication is an implicit exchange—respondents are more willing to share information when they perceive their "time investment" is rewarded with "professional respect and emotional recognition." Incentives (e.g., gifts) may be provided as compensation for participation.
- 3) **Relevance Highlighting:** Emphasize how the research improves outcomes for "themselves or similar groups." Tailor value statements to their areas of concern to strengthen their perception of relevance.
- 4) **Empathy Building:** Researchers may appropriately share research background information or general observations to establish an "equal dialogue" relationship.
- 5) **Sensitive Topics:** When addressing sensitive topics, focus on "problem-solving" (e.g., "How do you think we can work together to improve this situation?"). This reduces defensive attitudes and encourages more honest expression.

4.4 56 Years Old and Above

4.4.1 Age Group Characteristics

Raised in a traditional social structure, their communication patterns are deeply influenced by Fei Xiaotong's "rural society" theory, shaping unique group traits. They place greater emphasis on privacy and safety, require more time to build trust, are extremely sensitive to health-related information, respect authority and professionalism, prefer face-to-face communication, and are more accustomed to using non-verbal cues (e.g., facial expressions, body language) to convey

information.

4.4.2 Relevant Research

Community participation studies emphasize that building trust with this age group requires certification from authoritative institutions and sustained interaction. Social Identity Theory (Tajfel & Turner, 1979) explains that when research institutions have formal ties to the respondent's community (e.g., senior universities, neighborhood committees), respondents categorize researchers into their "in-group," thereby reducing psychological distance. Additionally, face-to-face interaction significantly enhances this group's sense of security.

4.4.3 Strategies

- 1) **Survey Methods:** Face-to-face offline interviews are preferable to online questionnaires. The first interview must be conducted offline; subsequent interactions may offer telephone/video options. Online questionnaires should adhere to "elderly-friendly principles": no overly small fonts, no complex navigation, minimal jargon, and optional audio narration if needed.
- 2) **Trust Building:** Establish initial trust through official documents such as school introduction letters and research institution credentials. Researchers must demonstrate great patience, respect, and professionalism.
- 3) **Language Delivery:** Speak at a moderate, clear pace and avoid jargon. Encourage respondents to share stories and memories through active listening, and express sincere interest in and respect for their life experiences.
- 4) **Privacy Reinforcement:** Repeatedly and clearly explain confidentiality commitments and anonymity measures verbally. Ensure environmental privacy by selecting undisturbed, enclosed spaces and avoiding third-party presence. If audio/video recording is required for telephone/video interviews, inform respondents in advance and obtain consent to protect their right to information.
- 5) **Topic Transition:** Begin with life history and general experiences, transitioning to research topics very gradually. Use indirect questioning, projective techniques, and range-based options extensively. Emphasize that the research aims to improve services or policies for the elderly (e.g., linking health-related questions to improvements in healthcare).
- 6) **Time Allocation:** Allocate sufficient time, and split the survey into multiple sessions if necessary. This prevents information quality degradation due to fatigue and fosters a more harmonious relationship through prolonged in-depth interaction, significantly enhancing the depth and validity of subsequent communication.

4.5 Techniques for Cross-Age Communication

1. **Active Listening and Empathy:** Listen not only to the content but also to the emotions and unspoken needs. Activate the respondent's "sense of being understood" through nodding, eye contact, brief responses, and appropriate emotional reflection—this reduces defensive attitudes and promotes in-depth expression.
2. **Strategic Silence:** Offiong et al. (2023) found in their virtual community research that deliberately maintaining 3 seconds of silence after a respondent answers or hesitates (instead of immediately following up) increases information disclosure by 20%–30%.
3. **Keyword-Based Follow-Up:** Use keywords or concepts mentioned by the respondent to follow up (e.g., "You mentioned feeling 'very stressed' earlier—could you elaborate on what aspects of stress you're referring to?"). Emphasize generating questions from the data

rather than confining data to pre-set questions.

4. **Content Verification:** Summarize the information heard at appropriate times and confirm understanding with the respondent (e.g., "So what you're saying is... Is that correct?"). This creates a communication loop of "information encoding—information decoding—information feedback" and demonstrates respect for the respondent.
5. **Non-Verbal Cues:** During offline interviews, pay attention to changes in tone, speech rate, and body language—these may indicate sensitive points or unexpressed emotions. For example, sudden silence or leaning back may signal discomfort with a topic; accelerated speech or raised pitch may reflect emotional arousal. These cues can guide gentle further exploration.

Genuine in-depth research does not rely on techniques to "extract" information but rather builds sustainable trust relationships based on respect for individual differences. The privacy concerns of each age group are, in essence, unique communication languages—languages that require translation through academic rigor. By seeking understanding, we obtain authentic information; by showing respect, we build trust. Ultimately, this provides an academic research foundation that is both reliable and valid, and rich in humanistic warmth.

5. Practice-Based Learning and Improvement

5.1 questionnaire

During the project implementation process, we strictly followed the guidelines in this manual to advance various tasks, with the questionnaire design phase placing particular emphasis on scientific rigor and user orientation. To ensure the questionnaire could accurately capture target information and align with respondents' needs, we first launched pre-survey work: we designed and distributed a pre-questionnaire, focusing on investigating respondents' actual experiences with participating in various questionnaires in the past—including their participation frequency, difficulties encountered during completion, preferences for questionnaire question types/structures, and problematic design aspects of previous questionnaires that had led to a poor experience, while simultaneously collecting first-hand user feedback.

At the same time, we conducted a systematic literature review, organizing core theoretical frameworks in the field of questionnaire design at home and abroad, research findings on respondents' behaviors from a psychological perspective (such as cognitive load theory and methods for avoiding social desirability bias), as well as experiences and lessons learned from questionnaire design in similar projects.

We then conducted multi-dimensional matching and verification between the real user data obtained from the pre-questionnaire and the theoretical basis and practical cases extracted from the literature review: on the one hand, we used literature conclusions to calibrate design flaws identified in the pre-questionnaire; on the other hand, we used users' actual needs to reversely optimize the implementation methods of literature theories.

Finally, we integrated the verification results to develop a questionnaire that fully adheres to the laws of human psychology—one that not only avoids common issues such as cognitive fatigue and leading bias but also fully respects respondents' willingness to express themselves. This truly embodies the core "people-oriented" concept in every detail of the questionnaire, including

dimension setting, question logic, and language style.

5.2 communication

In the optimized design of communication methods, we first established a theoretical foundation through systematic literature review — we organized mainstream communication forms in the fields of sociology and psychology, conducted in-depth analysis of the suitable scenarios for different forms in terms of information collection efficiency and stimulating respondents' willingness to express themselves, and simultaneously focused on learning knowledge related to communication psychology, including empathic listening techniques, cognitive load management methods, and communication strategies to reduce respondents' defensive psychology.

Based on this theoretical foundation, we integrated the principle of "respect" throughout the entire process of practical communication:

- **Before communication:** We proactively informed respondents of the interview's purpose, estimated duration, use of information, and confidentiality commitment through written or verbal means in advance, safeguarding their right to know and right to voluntary participation.
- **During communication:** We avoided interrupting respondents' expressions, maintained a neutral and receptive attitude toward the views they shared, and replaced leading questions with open-ended ones such as "What do you think might be the reasons behind this situation?" Meanwhile, we adjusted our expression style according to the respondents' language habits.
- **After communication:** We took the initiative to ask respondents if they had any additional comments and informed them of follow-up feedback channels, ensuring they felt valued.

This communication model combining "theoretical support + humanistic care" directly promoted the dual improvement of reliability and validity:

- In terms of reliability: We reduced subjective biases through a unified communication framework, and at the same time, lowered the proportion of perfunctory responses from respondents based on trust-based relationships, ensuring the communication information from different respondents was characterized by comparability and traceability.
- In terms of validity: The empathic communication and low-defensiveness atmosphere encouraged respondents to express their true thoughts openly, avoiding "superficial responses"; meanwhile, adaptive communication forms enabled us to accurately reach core information. Ultimately, the collected information was not only authentic and reliable but also accurately aligned with the project's needs.

References

- [1] Mondschein CF, Monda C. The EU's General Data Protection Regulation (GDPR) in a Research Context. 2018 Dec 22. In: Kubben P, Dumontier M, Dekker A, editors. *Fundamentals of Clinical Data Science* [Internet]. Cham (CH): Springer; 2019. Chapter 5. PMID: 31314241.
- [2] Wen B, Zhang G, Zhan C, Chen C, Yi H. The 2024 revision of the Declaration of Helsinki: a modern ethical framework for medical research. *Postgrad Med J*. 2025 Mar 16;101(1194):371-382. doi: 10.1093/postmj/qgae181. PMID: 39671397.
- [3] International Ethical Guidelines for Health-related Research Involving Humans: Prepared by the Council for International Organizations of Medical Sciences (CIOMS) in collaboration with the World Health Organization (WHO) [Internet]. 4th ed. Geneva: Council for

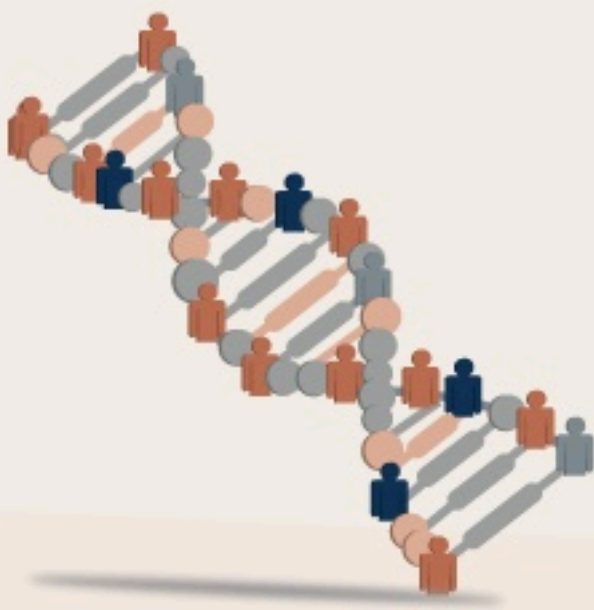
International Organizations of Medical Sciences; 2016. PMID: 40523065.

- [4] Nawrot O. The biogenetical revolution of the Council of Europe - twenty years of the Convention on Human Rights and Biomedicine (Oviedo Convention). *Life Sci Soc Policy*. 2018 May 16;14(1):11. doi: 10.1186/s40504-018-0073-2. PMID: 29770893; PMCID: PMC5955870.
- [5] Kaye J; Organisation for Economic Co-operation and Development. Building a foundation for biobanking: the 2009 OECD guidelines on human biobanks and genetic research databases (HBGRDs). *Eur J Health Law*. 2010 Mar;17(2):187-90. doi: 10.1163/157180910x12665776638821. PMID: 20443449.
- [6] Lenoir N. UNESCO's Universal Declaration on the Human Genome and Human Rights, 11 November 1997. *Rev Derecho Genoma Hum*. 1998 Jul-Dec;(9):119-41. PMID: 10335338.
- [7] Lachenmeier DW, Montagnon C. Convention on Biological Diversity (CBD) and the Nagoya Protocol: Implications and Compliance Strategies for the Global Coffee Community. *Foods*. 2024 Jan 13;13(2):254. doi: 10.3390/foods13020254. PMID: 38254555; PMCID: PMC10814485.
- [8] Illingworth S. Delivering effective science communication: advice from a professional science communicator. *Semin Cell Dev Biol*. 2017 Oct;70:10-16. doi: 10.1016/j.semdb.2017.04.002. Epub 2017 Apr 12. PMID: 28412537.
- [9] McPhetres J. Oh, the things you don't know: awe promotes awareness of knowledge gaps and science interest. *Cogn Emot*. 2019 Dec;33(8):1599-1615. doi: 10.1080/02699931.2019.1585331. Epub 2019 Feb 27. PMID: 30810476.
- [10] Lesen AE, Rogan A, Blum MJ. Science Communication Through Art: Objectives, Challenges, and Outcomes. *Trends Ecol Evol*. 2016 Sep;31(9):657-660. doi: 10.1016/j.tree.2016.06.004. Epub 2016 Jul 1. PMID: 27377601.
- [11] Ristori S, Scavone F, Bartolozzi C, Giovannelli L. The comet assay for the evaluation of gut content genotoxicity: Use in human studies as an early biomarker of colon cancer risk. *Mutat Res Genet Toxicol Environ Mutagen*. 2022 Jun;878:503477. doi: 10.1016/j.mrgentox.2022.503477. Epub 2022 Feb 24. PMID: 35649683.
- [12] Zhu, S., Lv, K., & Cheng, Y. (2025). The Impact of Digital Technology Innovation on Firm Performance: Based on the Corporate Digital Responsibility Perspective. *Business Ethics, the Environment & Responsibility*, 1. <https://doi.org/10.1111/beer.12785>
- [13] Spicer S. The nuts and bolts of evaluating science communication activities. *Semin Cell Dev Biol*. 2017 Oct;70:17-25. doi: 10.1016/j.semdb.2017.08.026. Epub 2017 Aug 18. PMID: 28823946.
- [14] Cypress BS. Rigor or Reliability and Validity in Qualitative Research: Perspectives, Strategies, Reconceptualization, and Recommendations. *Dimens Crit Care Nurs*. 2017 Jul/Aug;36(4):253-263. doi: 10.1097/DCC.0000000000000253. PMID: 28570380.
- [15] Fisher RP, Geiselman RE. The cognitive interview method of conducting police interviews: eliciting extensive information and promoting therapeutic jurisprudence. *Int J Law Psychiatry*. 2010 Nov-Dec;33(5-6):321-8. doi: 10.1016/j.ijlp.2010.09.004. Epub 2010 Sep 26. PMID: 20875685.
- [16] Babbie, Earl. *The Practice of Social Research*. 15th ed. Belmont, CA: Wadsworth, 2021
- [17] Jourard, Sidney M. *The Transparent Self*. 2nd ed. New York: Van Nostrand Reinhold, 1971.
- [18] Estl M. Exploration - technik oder Kunst [Interview - technique of art (author's transl)]. *Padiatr*

Padol. 1976;11(1):164-7. German. PMID: 1250617.

- [19] Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 50(2), 179-211.
- [20] Blau, P. (1986). *Exchange and Power in Social Life* (2nd ed.). Routledge.
- [21] Craig, D.W., Hunyadi, J., Walker, T.J. et al. Using a novel, multi-method approach to evaluate the quality of self-report survey data in organizational readiness research. *Implement Sci Commun* 6, 63 (2025).
- [22] Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry*, 11(4), 227–268.
- [23] Sarah R. Davies, Science communication is not an end in itself: (dis)assembling the science festival[J]. *International Journal of Science Education, Part B*, 2019, 9(1):40-53
- [24] Shupe Yuan, Tsuyoshi Oshita, Niveen AbiGhannam, Anthony Dudo, John C. Besley & Hyeseung E. Koh (2017) Two-way communication between scientists and the public: a view from science communication trainers in North America, *International Journal of Science Education, Part B*, 7:4, 341-355,
- [25] Prensky M. Digital Natives, Digital Immigrants Part 1[J]. *On the Horizon*, 2001, 9(5):1-6.
- [26] Asari Offiong et al., Maintaining community-engaged research with young people in a virtual setting[J]. *Progress in community health partnerships*, 2023, 17(2):329-337
- [27] Russell Cropanzano, Marie S., Mitchell Social exchange theory: An interdisciplinary review[J]. *Journal of management*, 2005. 31(6): 874-900.
- [28] Johanna I. Seitenbach, An Exploratory Study of How Millennials Approach and Communicate Mental Health in the Workplace[J]. 2019

This handbook aims to develop a two-way evaluation system and a guide for iGEMers for social research in the field of synthetic biology.



2025 NUDT-CHINA