New-media arts-based public engagement projects could reshape the future of the generative biology

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► Additional material is published online only. To view please visit the journal online (http://dx.doi.org/10.1136/medhum-2020-011862).

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Accepted 24 April 2020
Published Online First 28 May 2020

ABSTRACT

Research in the sciences of new-media arts aims to develop original research questions and borrows many different interdisciplinary research methodologies that often involve collaboration with professionals from non-art fields to provide real investigations. Over the last four decades, new-media arts provided unlimited strategies to integrate the laypeople into real interactive conversations allowing them to express their opinions and reflect their concerns regarding boundless scientific, environmental, political and ethical issues. Within this context, this article illustrates the parallel and growing attention to perform effective joint public engagement projects between both new-media arts and biological science domains and how biological science could benefit from the new-media arts projects to allow the laypeople to actively participate in decision-making processes regarding critical biological issues that seek more open and democratic biological investigations. This article, therefore, monitors the developments of public engagement as a concept in biological sciences and its practical principles, which they have been enhanced under the influence of today's new-media arts strategies of engagement. As an extension of the existed efforts, the article, finally, highlighted one of the most recent international conversation led by the author regarding an assumed new-media arts protocol to use stem cells in new-media arts labs and the role of such protocol to secure the highest standard level of public engagement, by which the laypeople could control and reshape the future of generative biology and personalised medicine.

COMMON CONCERNS

Although art and science are different courses of human endeavours, both domains have maintained a joint concern regarding effective communication with the laypeople as the common target group of their productions. Both disciplines seek to communicate a wide spectrum of knowledge and its related human experiences to the public.

In fact, in the renaissance, art was a powerful means to communicate both artistic and scientific ideas. Through the early history of modern science, several scientists tried to promulgate the outputs of their research, such as Michael Faraday who spent a considerable amount of time trying to communicate his research by significant illustrations.[1] However, over time and by the growing academic rules of the scientific societies, scientists became less confident in disseminating their research under the public way including art. In 1969, the editor of the *New England Journal of Medicine*, Franz Ingelfinger, decided that no research could be published in his journal if it had already been exposed in public.[2] The Ingelfinger rule spread quickly among journals and remains an academic rule of journal publication today. This is how publications including artistic–scientific illustrations, as the most primary traditional ways to communicate with the laypeople, were withdrawn from the public arena. Likewise, from the beginning of the 20th century, particularly after photographic techniques had been spread popularly as an artistic medium, the pictorial scenes in visual arts began to be replaced by abstract, conceptual or symbolic compositions as artists recognised that art's role must be much more than imitating nature.[3] Artists, therefore, began to adopt complicated insights to explain and reinterpret their ideas. Clearly, it was so difficult for laypeople to grasp these kinds of artistic practices at the same level of their understanding of the pictorial forms. This is how the artistic community also lost a significant space of its wide public ground.

In the middle of the 20th century, the term 'scientific' began to take on negative connotations, evoking more doubts than certainties due to two main challenges; (1) certain physical phenomena, natural crises, or biological and genetic disease, in which science fails to solve or even to describe until now. (2) The uncontrolled development of certain science productions produced as a part of the promise by scientists to enhance people's lives, but that lost credibility due to their negative impact, such as the drugs called 'Thalidomide' and 'DDT', Chernobyl and many other problems that science has produced, in addition to some that fears have grown in recent years about the capacity of science to intervene adversely in various dimensions of human life.[4] Further, pollution and physical harm continue to be among the unintended consequences of many beneficial technologies such as electronics, pesticides and vaccines. All these problems seriously affect people's trust level in science.[5]

In this context, Bultitude found four cultural factors that have influenced the separation of science from society: the loss of expertise and authority of scientists, a change in the nature of knowledge production, improved communications and proliferation of sources of information, and the democratic deficit.[6] This is why it was crucial for scientific communities to turn back to the laypeople and all non-scientist stakeholders to regain their trust as most science remains publicly financed and, therefore, demands the public's support. Thus, currently, most of the prestigious academic institutions and professional communities devote myriad efforts to ensure that they have effective strategies adopted for successful science communication, by

To cite: Ahmedien DAM. *Med Humanit* 2021;**47**:283–291.

which their scientific projects are appropriately promulgated to the open society in order to raise the public awareness of today's sciences towards building knowledge-based societies and to reshape the processes of sciences production to be more democratised and trusted processes.

As an academic discipline, science communication is a relatively new field, which is developed under three levels of integration: 'Scientific Literacy', 'Public Understanding of Science' and 'Public Engagement'. Although all of these phases aim at making science open and understandable for non-scientists, every one of them adopts different communicative methodologies.[7]

In principles, the communication processes need four basic elements: sender, message, transmitter and receiver. The relationship between these four elements determines the quality of the communication process. In fact, the most classical form of science communication depends on the message itself that often had been conflated with studies of 'scientific literacy' or 'public understanding of science', which refer to what non-scientists know about science and how to increase this knowledge but without allowing people to discuss. Likewise, traditional arts used in the early science communication attempts were always dependent on the traditional forms of art (painting, sculpture and so on) that is always presented in a closed ready-made visual message delivered to the audience through a static medium, in which there is no way for the audience to inform the creator their feedback.

This kind of knowledge transference tends to be described as 'deficient' in quality and quantity in comparison with the knowledge of scientists. In this 'deficit model' of public understanding of science, there is a normative element that the deficit should be remedied, and the remedy is to transmit knowledge from scientists to laypeople. The deficit model, hence, was built based on the assumption that increasing the public's knowledge will also lead to more positive attitudes toward science.[8] This is why it is always in the form of one-way communication and, therefore, concentrates on the message (amount of information) that can be transmitted to the laypeople verbally, or visually but ignoring the transmitter's role. However, research consistently indicates that greater knowledge does not necessarily generate more positive attitudes; and more science communication does not necessarily result in higher levels of knowledge,[9] even creating a valuable piece of art to deliver scientific concepts cannot be a guarantee of successful science communication processes as long as the artistic piece possesses one-way visual communication, within the context of the deficit model that sent the content of the intended message, without any chance to collect the public response that must be used to evaluate and revise that message. In response, Hilgartner noted that much science communication is framed by the idea that science is emitted by scientists and transmitted by journalists or artists to the public. In this regard, the model is similar to the sender–transmitter–receiver model of classical communication studies. The final destination of this pure knowledge is a passive, uncritical public, who listen but do not speak. As Alan Irwin explained, the problem is that most of these early approaches are about deficit rather than dialogue.[10] The deficit should not obstruct the broader point that deficiencies of understanding are inevitable on all sides, and indeed serve as a powerful motivation for dialogue and engagement rather than being an obstacle or a barrier to participate.[11]

APPROACHES TO PUBLIC ENGAGEMENT

At the beginning of 21st century, a considerable shift could be observed in the ideology of the communication of science that had been developed from the deficit model to encourage two-way dialogues between experts and non-experts. The mutual dialogue-based communication concentrated on the processes of communication, in which the transmitter must play a crucial role; therefore, the message (scientific content) can be revised and modified through the receivers' feedback. Within this context, the National Co-ordinating Center for Public Engagement defines public engagement as a myriad of ways in which the activity and benefits of higher education and research can be shared with the public.[12] Thus, several frameworks were built to engage the laypeople in science production, when scientists decided to listen to the members of the public communities in order to address their needs and measure the impact of science productions so that they can build mutual trust.

In this regard, Wildon identified the most important ways and activities adopted by scientific societies to hear from the public or even to interact with them: surveys, deliberative polls, conversations with focused groups, integrating citizen juries, co-ordinating consensus conferences, managing public debates and so on. In an advanced step, scientific communities considered social media tools as a powerful way; on the one hand, it serves scientists to act as a dispersed public voice for science, and on the other hand, to let laypeople record their attention degree to be a considered part of the scientists production metrics.[13] As the benefits become more apparent and dedicated metrics are developed to supplement scientists' portfolios, social media became an integral part of the researcher's toolkit. Altimetric projects, for instance, was developed by the Digital Science company, who designed a multi-colour donut in which every colour of it refers to a different source of recorded attention like blogs, Twitter, Facebook, LinkedIn and so on. The Altimetric donut exists now in almost every academic publication journal and it provides information regarding any immediate public attention of any research article. In this way, scientists can secure several ways to collect and analyse laypeople's feedbacks.

This phase of public engagement, however, received objective criticisms due to the relational degree of passivity and activity of the public in science production. Collecting the public and stakeholders' feedback is very important; however, this is not a high level of involvement. In this regard, Alan Irwin said, focus on the assumption, in such exercises and activities, that engaged publics are just 'out there' waiting for their views to be harvested, rather than being specifically shaped and constructed by the exercise themselves. Within the context of the communication processes, the first stage of public engagement cannot secure a real productive interaction because the transmission medium still performs as a passive connector in most of the previously mentioned activities identified by Wildon, by which laypeople and scientists can hear each other but without real interactions and every message sent from any party to the other one is still pure in its source and language.[14]

As engagement includes a different level of involvement of participants, in both art and sciences, the participation ladder of Arnstein is always used to classify the degree of participation which is categorised into three categories: (1) 'Nonparticipation' (this category perfectly matches with the deficit model of science communication, by which people are informed but not allowed to give feedback). It also matches with all traditional forms of art, through which viewers face visual content without possibilities to process their feedback. (2) 'Tokenism': at which the main aim of participation is the legitimisation of research and gaining support from citizens without giving them an actual influence on decision-making (this category is fit to describe several activities of public engagement, in which public can interact but without

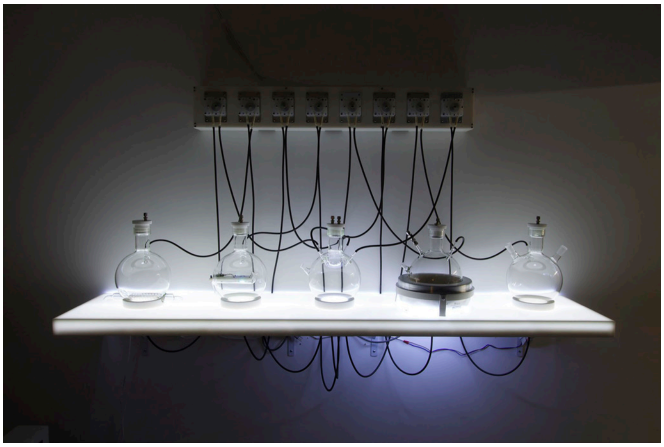


Figure 1 Adam W Brown and Robert Root-Bernstein. ReBioGeneSys: Generative hyper installation processes. 2015, Prix Ars Electronica, Austria. This kind of installation represents one of the most primary strategies of public engagement in new-media art by building a laboratory experiment within the context of a new-media art project, by which viewers can monitor, interact and control the outputs.

participation in decision-making). The early period of new-media arts also can be described under this category, at which observers can process their feedback but they cannot control the processes or decide regarding the core system of the artwork. Finally, (3) 'Citizen Power': at which scientists take the input of citizens seriously so that the public can practically participate in decision-making, and this is always what most effective public engagement strategies are looking for. This third phase is implemented perfectly within the context of the contemporary interactive new-media art trends like interactive art, game art, bio-art and more. However, in terms of science communication, there are always several obstacles that prevent delegation of the power to the public to take the responsibilities of scientific decision-making; this is why, recently, unlimited numbers of scientific institutions direct their eyes towards the methodologies used in new-media arts as an ideal form of impactful science communication (see online supplemental material).

New-media arts as a science of public engagement in biological science

Research in the sciences of new-media arts aims to develop original research questions and borrows many different interdisciplinary research methodologies that often involve collaboration with professionals from non-art fields to provide real investigations. New-media arts, therefore, can ideally facilitate the 'Citizen power' phase in Arnstein's participation ladder by offering a communicative channel allowing laypeople to share the scientific community in decision-making. Such practices are often operationally dynamic and in open-ended interactive or/and generative loops in order to engage the public as the main part of the system to process data-based interdisciplinary knowledge that is usually derived from real physical, computational or biological systems. In this context, interactive new media artists do not make a final, completed piece of art; instead, they seek to build communicative systems for the receivers, whose interactive actions with those systems bring an event-based artwork to life. In this way, arts-based science communication can achieve impactful outcomes for raising awareness, sharing decisions and shaping public policy.[15]

Practically, as a means of communication, interactive media arts depend on the nature of the transmitter instead of the message itself that, in this case, is always constituted within the context of the interactions between the interactors and the transmitter's interactive system. Operationally, the content of this transmitted message is processed as a result of the mutual communicative interactions between the operational strategies adapted by the creator to build the artwork's interactive system and the behavioural tactics adopted by the interactor as a co-creator. While the system's strategies secure sustainable interactive/generative actions in their predetermined course, participants' tactics secure diversified behavioural methods of updating and adapting the system's strategic orders so that the message's open-ended interactive loop is always being constituted, revised, modified, and updated by both parties of the communication process through the mutual executive actions between strategies and tactics. Within this context, the interactive New Media art–based science communication has demonstrated unparalleled potential to bring more of society to science and more science to society by adopting several kinds of strategies that in turn stimulate interactors to perform unlimited kinds of behavioural tactics to integrate with scientific society.

One of the most primary strategies is to build a laboratory experiment within a context of a new-media artwork in order to integrate the laypeople in the experience of scientific decision-making. In 2015, Adam W Brown, in collaboration with Robert Root-Bernstein, created a generative hyper installation processes entitled '*ReBioGeneSys*' (figure 1).

It is a system capable of forming the self-organising chemistries necessary to produce semi-living molecules and, perhaps, even protocells.[16] Although the observers here can witness the environment of the experiment, they cannot directly interact with the biological system. In contrast, this interaction barrier has been removed in the new-media experiment entitled '*Microbial Design Studio*' carried out by Mike Hogan and his colleagues in 2016.[17] Introducing a wider audience to the debates surrounding biological design and genetically redesigned products by building an easy-to-use biological system to integrate laypeople in a real experience of engaging directly with the design of transgenic products—in the domains of food, medicine or new materials—brings more awareness and responsibility to the users as they can relate to their potential implications in their daily lives.

While the strategy of building lab experiments sometimes allows observers to perform the experiment or even a part of it, the strategy of comparison-based investigations concentrates on the concepts beyond the scientific experiments by integrating the laypeople into two opposing conceptual systems in order to witness the meaning of one of them by comparing it with the other. The content of the message here is processed by the interactions between the two opposing systems and the participants' behavioural courses emitted in response to those systems. For an example, the participants witnessed cognitive and behavioural contrast induced by the interactive installation entitled '*Genesis of a Microbial Skin*' by Anne Marie Maes (figure 2).

It is a mixed-media installation project exploring the idea of intelligent beehives with a focus on microbial skin.[18] The first system she experimented with is natural micro-organisms and organic materials to create thin membranes and surfaces grown by a symbiotic community of bacteria and yeast cells. In the second system, on the other hand, she synthesised leather-like cellulose skin that was augmented with living technology. Although the strategy of comparison-based investigations is a powerful way to learn and understand, in most cases the observers have no chance to interact with the systems as the creator prefers to let

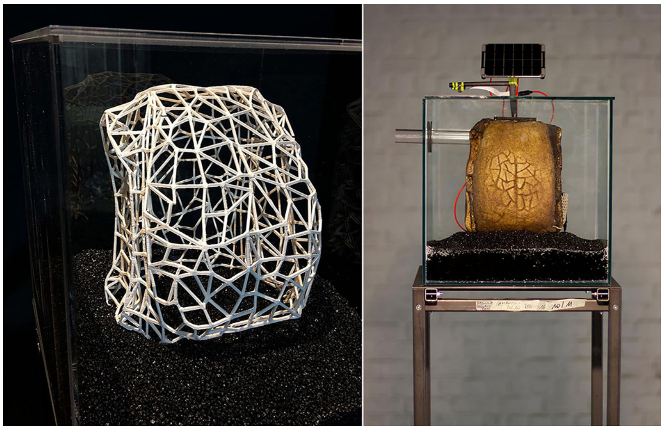


Figure 2 Anne Marie Maes. Genesis of a Microbial Skin: mixed media installations and a research project. 2016–2017. The lab of Chemical Engineering of the University Brussels (VUB) with the SEM (scanning electron microscope). This kind of installation aims at integrating viewers into opposite systems conceptually and operationally in order to allow them to compare both systems in order to understand how they differently act to perform the same functions.

observers concentrate on the comparison between the opposing operational concepts instead of interacting with each of them.

Recently, the strategy of gamification is considered as one of the most interesting approaches in arts-based science communication. Gamification strategy depends on the entertainment-based learning approach. Through several biological games, biologists attempted to communicate to laypeople and, simultaneously, collect their responses. The game here, as an interactive strategy, offers a chance for laypeople to adopt supervised or/and unsupervised behavioural tactics in response to the predetermined conditional algorithms of the system, through which biologists and analysts can collect data beyond the interface of that game to revise their system and update their decision.[19] For instance, several serious games have been designed to educate and train healthcare professionals to avoid medical errors or in rehabilitation processes, to reproduce the repetitive tasks that have to be done by the patient, acting as players. Other models of bio games, which are designed to interactively witness biological concepts, include Foldit as one of the most successful examples, through which the creation of accurate protein structure models has been turned into a game, and players are responsible for deducing the structure of proteins that have been difficult to ascertain using more conventional approaches.[20] Players can play individually, or within a team, and compete against one another within a points system. Players interact through real-time internet relay chat (IRC) during the game with any other individual who is playing, through which a global network takes place to disseminate the intended concept and collect the global response immediately.

Figure 3 Ani Liu. Spermatozoa: Interactive-generative installation. 2017, MIT New Media Art Gallery, USA. This generative installation is an ideal example to demonstrate how new-media arts could reflect public concerns about the ethical issues regarding biopolitics and legislative laws related to processing biological material.

Although most of the previous approaches deal with behavioural reactions of the interactors as data that can be processed through the artwork system to revise and update its outputs, the strategy of embedding data depends on deriving specific biological data from the creator or interactor or both together to be processed through the system so that the creator and interactor equally join each other to build an autonomous system based on unsupervised internal biological tactics. In response to the 2017 US President Donald Trump's executive order that cut off all US funding to international NGOs whose work includes abortion services or advocacy, Ani Liu carried out her interactive installation entitled '*Spermatozoa*' (figure 3).

It is an ideal example to demonstrate how new-media art bridges scientific society, government and public society in one unified arena to communicate.[21] Liu used a phenomenon known as galvanotaxis, where cells migrate towards a specific charge in an electric field. She used a brain–computer interface to read the electrical signals from her brain, and these signals were translated into commands for a microcontroller. Through these commands, the microcontroller moderates the charges on a circuit on which semen is placed. Therefore, the directional motility of sperm is gained. This system secured inner and outer communicative messages to communicate with laypeople. This system was developed later by facilitating the system to be connected with the participants in order to open the communicative message. This is similar to what happened in Refik Anadol's interactive artwork entitled *Engram* (figure 4), by which data derived from the participant's brain can sustainably reshape the form of the artwork.[22]

After that, the concept was developed into brain-to-brain communication, through which participants themselves used a dual system to communicate neurally. Recently, unlimited numbers of additional strategies were developed to exchange real data derived from the laypeople and several biological databases to process them within the interactive context of the artwork, by full support from several scientific non-governmental institutions.[23]

New-media arts could promise the future of generative biology

Although there have been successful art-based science communication attempts in biology, public engagement projects in biological science, particularly, face huge challenges. An analytical study published in 2016 by CellPress' *Trends in Ecology and Evolution* refers to among 200 current art-science projects in the USA, the rate of the art-science initiatives in biology is the lowest

Figure 4 Refik Anadol. Engram: Interactive-generative installation based on neural data. 2018, Pilevneli Gallery. Via neural information derived from participants themselves, this kind of interactive–generative system involves participants' biological data as the operational element of the system itself so that participants can witness the experiment as a core part of it.

among other scientific domains.[24] In response, several institutions have tried to launch initiatives for biologists and artists to unify their endeavours devoted to more effective public engagement projects, by which the laypeople can control and participate in decision-making processes towards more democratic, legal and ethical progress in the critical biological investigations.

In the middle of May 2016, the International Society of the Arts, Science, and Technology LEONARDO, as the highest prestigious society in the arts, science and technology, announced an open call to support art-science initiatives directed towards cancer research, in order to investigate whether combining the principles of art, science and technology with that of cancer biology can advance cancer research. The caller Dhruba Deb at the Center for Therapeutic Oncology Research, Southwestern Medical Center, Dallas, TX, encouraged insights related to innovative, cutting-edge topics that combine scientific methodologies with artistic practices that lead to establishing new paradigms in the prevention, diagnosis and treatment of, and an eventual cure for, cancer, providing novel perspectives for oncologists, beyond what has been revealed by biological research alone. Within this context, on 1 June 2018, I provided a proposal that sheds light on the role of the recent stem cell research in cancer treatment. The proposal assumed a protocol template designed to manipulate stem cell research in cancer within the context of cooperation between the biology labs and the new-media arts labs.[25] This template, therefore, aims at outlining a potential new-media arts protocol to use stem cells (NMAP-SC), towards a public understanding of stem cells with new-media arts lab's tools, applications and vision. As stem cell research is populated by big data, such as single-cell technology, transcriptomes and epigenomes of different development stages, it is often difficult for the lay public or other stakeholders, who are not experts in the life sciences, to understand what biologists research and what its relevance is, as often stem cell research leads to long-term impact in our lives, resulting in breaking social support and raising vague ethical and cultural issues.[26] This is why I have been highly encouraged to raise wider debates in order to develop the assumed outlined protocol towards a beta version one. Over a span of 10 months (from May 2018 to June 2019), I raised international debates with more than 600 biologists and new-media artists. At the end of June 2019, the beta version has been finished and validated on the Figshare database to be widely discussed.[27]

The beta version of the NMAP-SC, as a template-based protocol, provides powerful tools for new-media artists, biologists and stem cell scientists in order to plan joint public engagement projects to promote stem cell research as open science. The protocol seeks to use the sciences of new-media arts to build an interactive transitional channel that can concentrate on three theoretical and practical approaches that can be used to

1. Clarify, simplify and promulgate conceptual issues regarding stem cell research.
2. Disseminate stem cell research outputs into the public arena.
3. Transfer stem cells as a biological material from bio labs to new-media arts labs as a hyper-material.

By these three approaches, an interactive, iterative and evaluative concrete framework can be built to integrate laypeople smoothly into stem cell research.

The protocol is divided into four packages of questions (A, B, C and D), every one of them designed to be answered by a specific group, not solely, but through discussions with the other stakeholders. Collecting all answers from the four questions packages can draw out unlimited executive plans for new media art–based public engagement projects in stem cells and this is the purpose of this protocol. The four questions packages were essentially designed to stimulate an interactive inclusive dialogue among all related parties and stakeholders so that a high level of integration can be secured.

Question group A

This group of questions were designed for biologists and stem cell researchers in order to decide the extent to which they are interested in a stem cell project, or a part of it, within the context of a new-media art project. This group is divided into three sub-sections questions: A1 is to discuss the validity of simplifying and disseminating the complicated concepts related to a stem cell project into the public arena by the new-media art project. A2 is to investigate the possibilities of disseminating the outputs of a stem cell project by a new-media art project. A3 is to discuss the validity of transferring stem cells as a hyper-material to the new-media labs in order to process it within the context of new-media arts practices.

Question group B

This group was designed to be discussed between scientists and artists equally regarding the intended kind of stem cell that is going to be used in the intended projects.

Question group C

This question group was designed to be answered by new-media artists after discussion with biologists regarding the potential final form of the intended new-media art project. Through answering these questions, new-media artists will have a chance to deliver information regarding the potential capacity of the intended project, through which the stem cell research project/experiment can be interactively promulgated by the technical, conceptual and aesthetic dimensions of the intended new-media art project.

Question group D

This question group aims at determining the target stakeholders in the joint public engagement, outlining the potential impact and expecting the potential further development in the intended project to update the laypeople.

A 10-question survey has been designed to measure the satisfaction rate of the NMA-SC protocol (table 1). From July 2019 to

Table 1 Questions asked to experts to measure their satisfaction rate regarding using the assumed protocol

Question themes	Questions	Analysis			
		Respondents' numbers			
Respondents' classification		Bio	NMA	Other	Total
Q N: 1	Are you a biologist or new-media artist or other?	169	227	33	429
		Satisfaction rate			
Respondents' satisfaction		Bio	NMA	Other	Average
Q N: 2	How satisfied are you to work in a public engagement project through your stem cell research project/ experiment to promulgate your research outputs as an open science?	70%	82%	76%	76%
Q N: 3	How likely is that you would recommend this template as a protocol to build a new-media-art-based public engagement project in order to disseminate stem cell research outputs as open science?	62%	79%	69%	70%
Q N: 4	How satisfied are you with the balance in the workflow between biologists and new-media artists in the template?	87%	95%	91%	91%
Q N: 5	How likely will custom-made new-media arts projects be able to disseminate stem cell research outputs within the context of this template?	60%	91%	80%	77%
Q N: 6	How likely will transferring stem cells and related biological material from bio labs to new-media labs validate several inspiring approaches for bio designers by working with new-media artists within the context of this template?	52%	60%	86%	66%
Q N: 7	How likely will new-media arts projects within the context of this template able to combine the public and several stakeholders in a comprehensive debate to reveal the common interests and concerns revolved around the future of the stem cell research as an open science?	70%	86%	78%	78%
Q N: 8	How likely are you able to contribute to disseminate or/and develop this template individually or/and through your institution?	72%	79%	74%	75%
Satisfaction rate total average					76.1%
Respondents' free comments		Respondents' numbers			
		Bio	NMA	Other	Total
Q N: 9	Please, tell us what do you think, your comments and suggestions to develop the template	117	219	16	352
Q N: 10	Add your contact information if you want (optional) If you would like to receive informative emails regarding the project and potential cooperation with you, please add your contact information	117	219	16	352

November 2019, the survey questionnaire was circulated among a sample of new-media artists, members of the public and academic society. Besides, a private link of the survey was sent to more than 1867 new-media artists and biologists at the most prestigious academic institutions in biology and new-media arts worldwide, and additionally, LEONARDO announced the survey on its official website in order to attract people in the wider communities.[28]

About 429 replies were collected, representing a valid responses rate of 22.9%. We analysed the respondents' responses as examples of the academic community of scientists and new-media arts scholars to science communication. While new-media artists represented about 53% of all respondents, the participation rate of biologists was recorded at 39.50%, and 7.50% of respondents belonged to other specialisations (figure 5). Among about 19 countries, USA, Sweden and UK recorded the highest numbers of respondents, respectively (figure 6). In conclusion, the total average of the participants' satisfaction was 76.10% (figure 7).

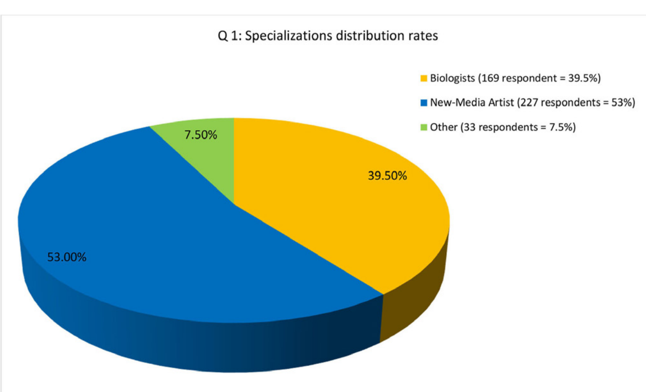


Figure 5 Graph compares the rates of participation from biologists, new-media artists and other fields to respond to the survey carried out to measure the satisfaction rates regarding using the assumed protocol to use stem cells in new-media arts projects.

The protocol was slightly modified according to the received feedback to be in a post-beta version.[29] According to the last modified version of the protocol, the intended initiative could be raised by new-media artists or biologists and discussed between both of them. Therefore, biologists can describe their experiment by answering all points given in the red part of the protocol and which approach (one of the three aforementioned approaches) they want to adopt in order to integrate the lay people into their investigation. Then, after discussion, artists could be invited to build their co-project inside the biological lab or transferring the required material to the new-media lab. Artists can describe their co-project by answering all points given in the blue section of the protocol. Finally, the intended output of the public engagement project could be described by artists and scientists by filling the green section of the protocol.

In this context, the modified protocol is positively correlated with the assumed concert evidence-based, iterative model for scientific outreach designed by Johnna Varner who emphasised that outreach activities can be conceptualised by three phases: development, implementation and evaluation.[30] The dialogue between biologists, new-media artists and stakeholders to answer all the template's questions can guarantee a successful executive protocol, through which Varner's three phases are achieved within a new-media art project in order to promulgate stem cell research as open science. Within the context of this methodological shift, art-based public engagement projects in generative biological

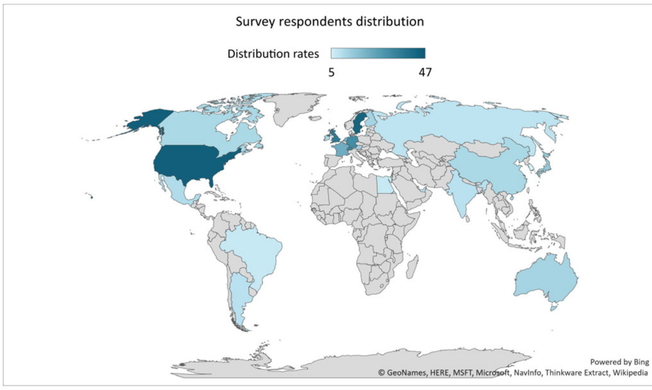


Figure 6 Graph illustrating the global distribution of respondents to the survey carried out to measure the satisfaction rates regarding using the assumed protocol among biologists, new-media artists and other specialisations. USA, Sweden and UK recorded the highest numbers of respondents, respectively.

sciences have great potentials to inform people about the benefits, risks and other costs of their decisions, thereby allowing them to make sound choices. Biologists, through these kinds of initiatives, can receive practical training about how to communicate with the diverse public. As avoiding the deficit model remains the golden rule to achieve impactful science communication processes, adopting new-media arts methodologies could greatly help scientists to reform the future of generative biology.

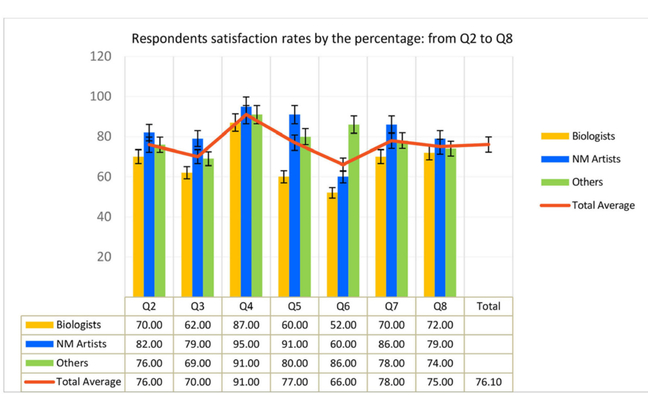
CONCLUSION

Although art and science have common concerns regarding communicating with the laypeople, both domains adopted several different paths to engage the lay society in their course of thinking. However, art has always been an effective way of science communication, but due to the unparallel requirements needed by complicated scientific investigations, particularly in generative biology, the classical forms and traditional mediums of art are no longer fit for effective public engagement projects because they depend on sending a one-way communicative message that cannot absorb the experimental procedures required to involve viewers in a constructive investigation. This is why scientific society supports the experimental strategies derived from new-media arts. However, new-media arts in their practical frames are not a pure path; they are interdisciplinary practices that always need a special creator who can absorb several different contents in different fields to be a new-media artist. Also, this kind of practice needs open-minded scientists who can joint new-media creators to produce effective public engagement projects. Within this context, the aforementioned protocol came to facilitate flexible paths, at which new-media artists and biologists can raise a constructive discussion. It is, therefore, to build public engagements projects individually, and also mainly to build a global agreement between biologists and new-media artists to reach a constitutional platform, by which the laypeople can interact, share and control issues regarding their rights to decide their biological future.

In fact, applying this protocol could strongly lend credibility to the assumption that contemporary new-media arts' strategies of public engagement could reshape the future of generative biology from several aspects:

First, public engagement strategies should be a part of every proposal of complicated biological experiments. Therefore, biologists must be trained to processes their outputs or a part of within the context of new-media art projects. Second, transferring stem cells and related biological material from bio labs to new-media labs could validate several inspiring approaches for bio designers by working with new-media artists within the context of this protocol in order to functionally disseminate the biological products like wearable technology and soft robotics in our daily life. Third, according to the first and the second points, the ethical issues regarding the code of practice and the code of conduction in generative medicine could be developed as the laypeople will be given a chance to control their biological future under the influence of generative biology.

Therefore, new-media arts can ensure the maximum level of the engagement of the public towards research, which is considered of the foremost urgency especially at times where experts are deemed as holding alternative facts. Through its adopted practical approaches, the proposed protocol priorities intersection and bridging between lay population and researchers in order to explore different venues to bring research to the general public, allowing and requesting their contribution will be the norm. Therefore, the more informed and included people feel, the more open they become so that generative biology can get societal legislation to continue their controversial research that usually raises several ethical and cultural issues. And, therefore, generative medicine research will be much more targeted to the needs of society.



	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Total
Biologists	70.00	62.00	87.00	60.00	52.00	70.00	72.00	
NM Artists	82.00	79.00	95.00	91.00	60.00	86.00	79.00	
Others	76.00	69.00	91.00	80.00	86.00	78.00	74.00	
Total Average	76.00	70.00	91.00	77.00	66.00	78.00	75.00	76.10

Figure 7 Graph illustrating the satisfaction rates recorded by biologists, new-media artists and other fields regarding the assumed protocol to use stem cells in new-media art labs. The graph shows the response of every group on every question and the average satisfaction rate on the protocol totally.

Glossary

- *New-media arts*: New-media art is a comprehensive term that encompasses art forms that are either produced, modified and transmitted by means of new media/digital technologies or, in a broader sense, make use of 'new' and emerging technologies that originate from a scientific, military or industrial context.[31]
- *Public engagement*: Public engagement describes the myriad of ways in which the activity and benefits of higher education and research can be shared with the public. Engagement is by definition a two-way process, involving interaction and listening, with the goal of generating mutual benefit.[32]
- *Stem cells*: Stem cells are a kind of cells that have the remarkable potential to develop into many different cell types in the body during early life and growth. Stem cells are distinguished from other cell types by two important characteristics. First, they are unspecialised cells capable of renewing themselves through cell division, sometimes after long periods of inactivity. Second, under certain physiological

or experimental conditions, they can be induced to become tissue-specific or organ-specific cells with special functions.[33]

- *Generative biology*: The medical specialty that employs computer-aided analysis of the relationships between an individual's genes, cells, organ systems, other organisms and their environments to provide a greater appreciation of the complex behaviours seen in both health and disease and more personalised approaches to the treatment of illness and enhancement of well-being.[34]
- *Personalised medicine*: Personalised medicine is a move away from a 'one size fits all' approach to the treatment and care of patients with a particular condition, to one which uses new approaches to better manage patients' health and targets therapies to achieve the best outcomes in the management of a patient's disease or predisposition to disease.[35]
- *Thalidomide*: It is a drug that was marketed as a mild sleeping pill safe even for pregnant women. However, it caused thousands of babies worldwide to be born with malformed limbs. The damage was revealed in 1962.[36]
- *DDT*: Dichlorodiphenyltrichloroethane (DDT) is an insecticide used in agriculture. DDT was a commonly used pesticide for insect control until it was cancelled in 1972. Following exposure to high doses, human symptoms can include vomiting, tremors or shakiness, and seizures. Laboratory animal studies showed effects on the liver and reproduction. DDT is considered a possible human carcinogen.[37]
- *Chernobyl disaster*: On 26 April 1986, a sudden surge of power during a reactor systems test destroyed Unit 4 of the nuclear power station at Chernobyl, Ukraine, in the former Soviet Union. The accident and the fire that followed released massive amounts of radioactive material into the environment.[38]
- *Science communication*: Science communication is the practice of informing, educating, sharing wonderment and raising awareness of science-related topics. Science communication is a matter of transmitting information about science from scientific experts to the public. The most prominent views assume that the transmission is to be effectuated through education in a formal school setting or (re)education through mass media.[39]
- *Public understanding of science*: The phrase 'public understanding of science' refers to a dual meaning, as both public attitudes and understanding of scientific concepts and developments, and also the field of research and pedagogical approaches relating to those attitudes and understandings.[40]
- *Scientific literacy*: Scientific literacy or science literacy encompasses written, numerical and digital literacy as they pertain to understanding science, its methodology, observations and theories.[41]
- *Deficit model*: In studies of the public understanding of science, the information deficit model or science literacy/knowledge deficit model attributes public scepticism or hostility to science and technology to a lack of understanding, resulting from a lack of information.[42]

Acknowledgements Special thanks are due to Dr Clara Novo, stem cell researcher at The Babraham Institute, Babraham Research Campus, Cambridge, for her valuable time spent to discuss this essay with me.

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Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Artists and the public were involved with biologists in the survey conducted to rate the assumed protocol designed to use stem cells in new-media art labs. All participants including the public provided advice on key aspects to enhance the design of the template-based protocol from several perspectives, including the outline of the new-media art projects intended to be carried out with biologists under the protocol and their potential outcomes. All public participants will be re-consulted for the public dissemination of any product arriving from the assumed protocol.

Patient consent for publication Not required.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request. All data relevant to the study are included in the article or uploaded as online supplementary information (New Media Arts Protocol to Use Stem Cells (NMAP-SC) Figshare: https://figshare.com/articles/New_Media_Arts_Protocol_to_study_Stem_Cells_NMAP-SC_/6199325/3).

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NOTES

1. Jim Al-Khalili (2015), "The birth of the electric machines: a commentary on Faraday (1832) 'Experimental researches in electricity'", Philosophical Transactions of the Royal Society A: Mathematical, Physical And Engineering Sciences 373, no. 2039: 20140208, doi:10.1098/rsta.2014.0208.
2. A S Relman and Arnold S Relman (1981), "The Ingelfinger rule", *New England Journal of Medicine* 305, no. 14: 824–826, doi:10.1056/nejm198110013051408.
3. CLARE AP WILLSDON (2016), "Painting and photography—in focus", Tate, https://www.tate.org.uk/research/publications/in-focus/pegwell-bay-kent-william-dyce/painting-and-photography.
4. Edison J Trickett et al. (2011), "Advancing the science of community-level interventions", *American Journal of Public Health* 101, no. 8: 1410–1419, doi:10.2105/ajph.2010.300113.
5. He Miao (2017), "The science communication in context of new media—the case of science journalism", *Journalism and Mass Communication* 7, no. 8, doi:10.17265/2160-6579/2017.08.002.
6. Jucan Mihaela Sabina and Cornel Nicolae Jucan (2014), "The power of science communication", *Procedia—Social and Behavioural Sciences* 149: 461–466, doi:10.1016/j.sbspro.2014.08.288.
7. Jim Ryder (2001), "Identifying science understanding for functional scientific literacy", *Studies in Science Education* 36, no. 1: 1–44, doi:10.1080/03057260108560166.
8. Alan Irwin (2015), "Science, public engagement with", *International Encyclopedia of the Social & Behavioral Sciences*, 255-260, doi:10.1016/b978-0-08-097086-8.85055–2.
9. National Academies of Sciences, and Medicine, Division Education, and Committee Agenda (2017), "The complexities of communicating science", Ncbi.Nlm.Nih.Gov, https://www.ncbi.nlm.nih.gov/books/NBK425719/
10. Alan Irwin (1994), "Book review: Science and its publics: continuity and change in the risk society", *Social Studies of Science* 24, no. 1: 168–184, doi:10.1177/030631279402400113.
11. Alan Irwin (2014), "From deficit to democracy (re-visited)", *Public Understanding of Science* 23, no. 1: 71–76, doi:10.1177/0963662513510646.
12. Glasgow Caledonian University (2012), "National Coordinating Centre For Public Engagement | Glasgow Caledonian University | Scotland, UK", Gcu.Ac.Uk, https://www.gcu.ac.uk/theuniversity/communityandpublicengagement/nationalcoor
13. Alan Regenberg (2019), "Science and social media", *STEM CELLS Translational Medicine* 8, no. 12: 1226–1229, doi:10.1002/sctm.19–0066.
14. Jeanne Braha (2017), "Science communication at scientific societies", *Seminars in Cell & Developmental Biology* 70: 85–89, doi:10.1016/j.semcdb.2017.05.010.
15. Shannon D Scott et al. (2013), "Protocol for a systematic review of the use of narrative storytelling and visual-arts-based approaches as knowledge translation tools in healthcare", *Systematic Reviews* 2, no. 1, doi:10.1186/2046-4053-2-19.

16. Adam W Brown (2014), "Prix Ars", Prix2015.Aec.At, http://prix2015.aec.at/prixwinner/15303/.
17. Orkan Telhan and MH Karen Hogan (2017), "Microbial Design Studio: 30 Day Simit Diet", STARTS PRIZE, https://starts-prize.aec.at/en/microbial-design-studio/.
18. Filip Visnjic (2018), "Genesis of a microbial skin—beehives designed for urban environments", Creativeapplications.Net, https://www.creativeapplications.net/environment/genesis-of-a-microbial-skin-beehives-designed-for-urban-environments/.
19. Michael Gross (2015), "The joy of science communication", *Current Biology* 25, no. 1: R27-R30, doi:10.1016/j.cub.2014.12.014.
20. UW Center for Game Science (2017), "Solve Puzzles For Science | Foldit", Fold.It, https://fold.it/portal/.
21. A Liu (2017), "Project Overview ' Brain-Controlled Interface for the Motile Control of Spermatozoa—MIT Media Lab", MIT Media Lab, https://www.media.mit.edu/projects/woman-of-STEAM-grabs-back/overview/.
22. R Anadol (2018), "LEV2019_Refik Anadol Melting Memories: Engram As Data Sculpture / Espacio Fundación EDP—Iglesia De La Laboral", LEV Festival, https://levfestival.com/19/en/lev-gijon/refik-anadol-melting-memories-engram-as-data-sculpture-espacio-fundacion-edp-iglesia-de-la-laboral/.
23. Ryszard W Kluszczynski (2010), "Strategies of interactive art", *Journal of Aesthetics & Culture* 2, no. 1: 5525, doi:10.3402/jac.v2i0.5525.
24. Amy E Lesen, Ama Rogan, and Michael J Blum (2016), "Science communication through art: objectives, challenges, and outcomes", *Trends In Ecology & Evolution* 31, no. 9: 657–660, doi:10.1016/j.tree.2016.06.004.
25. Diaa Ahmed Mohamed Ahmedien, "Manipulating stem cells in the new-media labs: develop a protocol template toward an innovative understanding of cancer", *Leonardo*, 2019, 1-3, doi:10.1162/leon_a_01767.
26. Ryuma Shineha et al. (2017)., "Science communication in regenerative medicine: implications for the role of academic society and science policy", *Regenerative Therapy* 7: 89–97, doi:10.1016/j.reth.2017.11.001.
27. Diaa Ahmedien, "New Media Arts Protocol To Use Stem Cells (NMAP-SC), Beta Version" (PDF, repr., UK, 2019), Figshare, https://figshare.com/articles/New_Media_Arts_Protocol_to_study_Stem_Cells_NMAP-SC_/6199325/3.
28. Diaa Ahmedien, "New-Media Arts Protocol To Use Stem Cells (NMAP-SC)", Leonardo/ISAST, 2019, https://www.leonardo.info/opportunity/new-media-arts-protocol-to-use-stem-cells-nmap-sc.
29. Diaa Ahmed Mohamed Ahmedien, "New Media Arts Protocol To Use Stem Cells (NMAP-SC)", Figshare, 2019, https://figshare.com/articles/New_Media_Arts_Protocol_to_study_Stem_Cells_NMAP-SC_/6199325/3.
30. Johanna Varner (2014), "Scientific outreach: toward effective public engagement with biological science", *Bioscience* 64, no. 4 (2014): 333–340, doi:10.1093/biosci/biu021.
31. Oliver Grau, "New media arts", Oxford Bibliographies, Oxford University Press, 2016, https://www.oxfordbibliographies.com/view/document/obo-9780199920105/obo-9780199920105-0082.xml
32. National Co-ordinating Centre for Public Engagement, "What is public engagement?", NCCPE, 2018, https://www.publicengagement.ac.uk/about-engagement/what-public-engagement
33. NIH Stem Cell Information Home Page. In Stem Cell Information (World Wide Web site). Bethesda, MD: National Institutes of Health, U.S. Department of Health and Human Services, 2016, https://stemcells.nih.gov/info/basics/1.htm
34. Goodwin, B. Homology and a generative theory of biological form. *Acta Biotheor* 41, 305–314, 1993, https://doi.org/10.1007/BF00709368
35. National Health Services England, "Personalised medicine", NHS England, 2018, https://www.england.nhs.uk/healthcare-science/personalisedmedicine/
36. Ronald D. Mann, "Aspects of modern drug use", *Modern Drug Use*, 1984, 597–665, doi:10.1007/978-94-009-5586-8_8.
37. Matthew P. Longnecker, Walter J. Rogan and George Lucier, "The human health effects of DDT (dichlorodiphenyltrichloroethane) and PCBs (polychlorinated biphenyls) and an overview of organochlorines in public health", *Annual Review of Public Health* 18, no. 1 (1997): 211–244, doi:10.1146/annurev.publhealth.18.1.211.
38. NRC Library, "NRC: Backgrounder on Chernobyl Nuclear Power Plant Accident", Nrc.Gov, 2018, https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/chernobyl-bg.html.
39. Klemens Kappel and Sebastian Jon Holmen, "Why science communication, and does it work? A taxonomy of science communication aims and a survey of the empirical evidence", *Frontiers in Communication* 4 (2019), doi:10.3389/fcomm.2019.00055.
40. Amy Seakins and Marie Hobson, "Public understanding of science", *Science Education*, 2017, 443-452, doi:10.1007/978-94-6300-749-8_32.
41. E-an Zen, "Science literacy and why it is important", *Journal of Geological Education* 38, no. 5 (1990): 463–464, doi:10.5408/0022-1368-38.5.463.
42. Molly J. Simis et al., "The lure of rationality: why does the deficit model persist in science communication?", *Public Understanding of Science* 25, no. 4 (2016): 400–414, doi:10.1177/0963662516629749.

BIBLIOGRAPHY

Al-Khalili, Jim. "The birth of the electric machines: a commentary on Faraday (1832) 'Experimental researches in electricity'." *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 373, no. 2039 (2015): 20140208.

Anadol, R. ""LEV2019_Refik Anadol Melting Memories: Engram As Data Sculpture / Espacio Fundación EDP—Iglesia De La Laboral". LEV Festival.", 2018. https://levfestival.com/19/en/lev-gijon/refik-anadol-melting-memories-engram-as-data-sculpture-espacio-fundacion-edp-iglesia-de-la-laboral/.

Braha, Jeanne. "Science communication at scientific societies." *Seminars in Cell & Developmental Biology* 70 (2017): 85–9.

Brown, Adam W. ""PRIX ARS". Prix2015.Aec.At.", 2014. http://prix2015.aec.at/prixwinner/15303/.

Glasgow Caledonian University. ""National Coordinating Centre For Public Engagement | Glasgow Caledonian University | Scotland, UK". Gcu.Ac.Uk.", 2012. https://www.gcu.ac.uk/theuniversity/communityandpublicengagement/nationalcoordinatingcentreforpublicengagement/.

Gross, Michael. "The joy of science communication." *Current Biology* 25, no. 1 (2015): R27–30.

Irwin, Alan. "Book review: Science and its publics: continuity and change in the risk society." *Social Studies of Science* 24, no. 1 (1994): 168–84.

———. "From deficit to democracy (re-visited)." *Public Understanding of Science* 23, no. 1 (2014): 71–6.

Irwin, Alan. "Science, public engagement with." *International Encyclopedia of the Social & Behavioral Sciences* (2015): 255–60.

Kluszczynski, Ryszard W. "Strategies of interactive art." *Journal of Aesthetics & Culture* 2, no. 1 (2010): 5525.

Lesen, Amy E, Ama Rogan, and Michael J Blum. "Science communication through art: objectives, challenges, and outcomes." *Trends in Ecology & Evolution* 31, no. 9 (2016): 657–60.

Liu, A. ""Project Overview ' Brain-Controlled Interface for the Motile Control of Spermatozoa—MIT Media Lab". MIT Media Lab.", 2017. https://www.media.mit.edu/projects/woman-of-STEAM-grabs-back/overview/.

Miao, He. "The science communication in context of new media—the case of science journalism." *Journalism and Mass Communication* 7, no. 8 (2017).

National Academies of Sciences, and Medicine, Division Education, and Committee Agenda. "The Complexities of Communicating Science. Ncbi.Nlm.Nih.Gov.", 2017. https://www.ncbi.nlm.nih.gov/books/NBK425719/.

Regenberg, Alan. "Science and social media." *STEM CELLS Translational Medicine* 8, no. 12 (2019): 1226–9.

Relman, A S, and Arnold S Relman. "The Ingelfinger rule." *New England Journal of Medicine* 305, no. 14 (1981): 824–6.

Ryder, Jim. "Identifying science understanding for functional scientific literacy." *Studies in Science Education* 36, no. 1 (2001): 1–44.

Sabina, Jucan Mihaela, and Cornel Nicolae Jucan. "The power of science communication." *Procedia—Social and Behavioral Sciences* 149 (2014): 461–6.

Scott, Shannon D, Pamela Brett-MacLean, Mandy Archibald, and Lisa Hartling. "Protocol for a systematic review of the use of narrative storytelling and visual-arts-based approaches as knowledge translation tools in healthcare." *Systematic Reviews* 2, no. 1 (2013).

Shineha, Ryuma, Yusuke Inoue, Tsunakuni Ikka, Atsuo Kishimoto, and Yoshimi Yashiro. "Science communication in regenerative medicine: implications for the role of academic society and science policy." *Regenerative Therapy* 7 (2017): 89–97.

Telhan, Orkan, and MH Karen Hogan. ""Microbial Design Studio: 30-Day Simit Diet". STARTS PRIZE.", 2017. https://starts-prize.aec.at/en/microbial-design-studio/.

Trickett, Edison J, Sarah Beehler, Charles Deutsch, Lawrence W Green, Penelope Hawe, Kenneth McLeroy, Robin Lin Miller., *et al*. "Advancing the science of community-level interventions." *American Journal of Public Health* 101, no. 8 (2011): 1410–9.

UW Center for Game Science. ""Solve Puzzles For Science | Foldit". Fold.It.", 2017. https://fold.it/portal/.

Varner, Johanna. "Scientific outreach: toward effective public engagement with biological science." *BioScience* 64, no. 4 (2014): 333–40.

Visnjic, Filip. "Genesis of a microbial skin—beehives designed for urban environments." *Creativeapplications.Net* (2018).

WILLSDON, CLARE AP. ""Painting and Photography—In Focus". Tate.", 2016. https://www.tate.org.uk/research/publications/in-focus/pegwell-bay-kent-william-dyce/painting-and-photography.