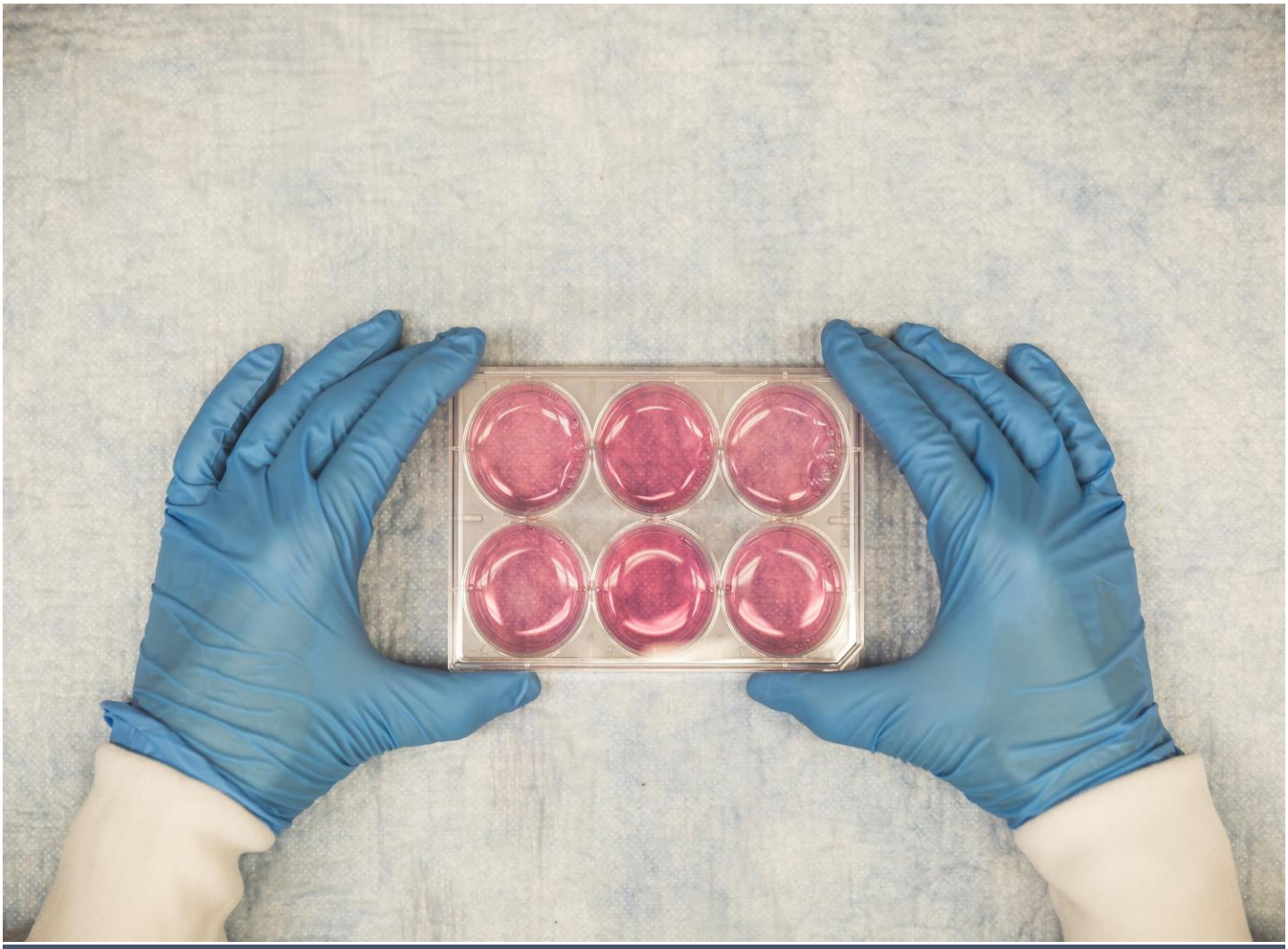

CRISPR ETHICS & IMAGINATION: AN EVALUATION OF THE ROLE OF DIY-CRISPR KIT IN CRISPR-CAS9 DELIBERATIONS

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CRISPR Ethics & Imagination: An Evaluation of the Role of DIY-CRISPR Kit in Crispr-Cas9 Deliberations

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LIST OF ABBREVIATIONS

DIY: Do- It -Yourself

CRISPR: Clustered regularly interspaced short palindromic repeats

DNA: Deoxyribonucleic Acid

RNA: Ribonucleic Acid

ODIN: Open Discovery Institute

COGEM: Commission on Genetic Modification

FDA: Food and Drug Administration

TA: Technology Assessment

pTA: Participatory Technology Assessment

SUMMARY

This thesis investigates the possible utility and value of DIY-CRISPR kits, introduced in 2016 by The ODIN company, in the context of assessment related discussions about the moral desirability of CRISPR-Cas9 technique which are conducted as part of technological assessment (TA) and participatory technological assessment(pTA) events. This kit which consists of materials and instructions required to make specific alterations to the bacterial genome at home is a product of the Do-It-Yourself biology movement. Currently, the use of the kit is limited to the collective (DIYbio community labs and events) and private settings (homes, garages, kitchens) of the DIYbio movement. The DIYbio movement is a worldwide phenomenon in which amateurs, students, hobbyists, scientists, artists, and designers are engaged in activities relating to biology and biological materials outside of scientific institutions.

Clustered regularly interspaced short palindromic repeats(CRISPR), also referred to as CRISPR-Cas9, is a genome editing tool that has been gaining the attention of scientists and ethicists around the globe over the past few years as it allows making site-specific modifications to genomes of organisms in a precise and inexpensive manner. To highlight why the kit might be of use to enrich the ethical debates on CRISPR, in this thesis, I analyze the quality of the current ethical discussions on CRISPR based on Swierstra's (2015a) argument about imagination of soft impacts improving the quality of ethical debates on emerging technologies. My analysis of the types of ethical arguments raised in favor of and against indicates that the ethical deliberations on CRISPR-Cas9 are poor in quality and less imaginative as their focus has been on hard impacts rather than on soft impacts.

Furthermore, to emphasize how the kit might improve the ethical deliberations, I looked at activities conducted within the DIYbio movement which performs a similar role. Based on researches conducted by Vaage (2016) and Holmberg & Ideland, (2016), bioart was identified as an activity that raises questions and reflections, different from the usual concerns about hard impacts (such as safety and security risks) by evoking imagination. Drawing on this finding, I then moved to evaluate if the kit and its use has a potential to trigger imagination. Concepts described within theories of moral philosophy which hold that moral reasoning is imaginative, were then used to formulate an evaluation criterion. Theories of moral imagination, as outlined by

pragmatists like Dewey, Johnson, Fesmire and reviewed by Coeckelbergh, describes the roles imagination perform in situations that novel and frustrates one's moral habits. For the purpose of evaluation, I translate the roles of moral imagination, viz. envisioning possibilities for action and their consequences, and empathetically projecting into others' experience, as being influenced by the kit's conceptual framing, use in different contexts and contextual framing, and the narrative-like structure of texts associated with it. The evaluation basically addresses the research question of this project: *Can DIY-CRISPR kit enrich the ethical deliberation and evaluation of CRISPR technology by stimulating imagination? If so how?*

Based on the results of the evaluation, the expert opinions and user experiences, I infer that the kit has limited imaginative potential. In the context of collective use settings, I argue that imagination required for anticipation of both hard and soft impacts may be triggered depending on the contextualization of the setting. Whereas in private settings, the kit seems to invoke imagination about (or relevant for the anticipation of) hard impacts rather than of soft impacts. The kit, though limited in its potential, I argue can enrich deliberations in TA and pTA events on CRISPR. To improve its potential for triggering imagination, I suggest attaching the kit with a story(ies) and/or contextualizing its use within a story that poses a moral problem and is carefully worded with metaphors in such a way that it allows for developing empathy towards the other.

Keywords: DIYbio movement, CRISPR-Cas9, DIY-CRISPR kit, moral imagination

INTRODUCTION

"You Could Soon Use CRISPR To Biohack In Your Own Home" reported one source (Ossola, 2015), "What Happens If Someone Uses This DIY Gene Hacking Kit to Make Mutant Bacteria?"(Pak, 2014) a study enquired, while the heading of a *Scientific American* article read "Mail-Order CRISPR Kits Allow Absolutely Anyone to Hack DNA"(Sneed, 2017). All these titles, besides creating a slight panic in the reader because of the close proximity of words "Hack/Biohack" and "DNA," have one thing in common: the DIY-CRISPR kit. Within the context of this thesis, the DIY-CRISPR kit refers to the "DIY Bacterial Gene Engineering CRISPR Kit" manufactured and sold on The ODIN company website for $159[1]. This kit contains all the materials, equipment and instructions required to modify *E.coli* bacteria to grow on a streptomycin medium The panic amongst members of the scientific community and public associated with the kit which gives access to the genome editing technology of CRISPR began with Josiah Zayner's (2015) crowdfunding campaign. He started introducing his idea, on the campaign page, with the intriguing question of "what if you had access to synthetic biology tools like CRISPR?" and ended with a promise that the CRISPR technology-based engineering kits developed by him would allow everyone, even those without experience in Biotechnology, to learn about CRISPR by actually performing experiments.

This thesis project aims to discern the probable value of using the DIY-CRISPR kit under the context of technology assessment events and workshops, especially during participatory Technology Assessments (pTA) in which the general public is invited to share their concerns and opinions about the technology being developed. The use of the kit has so far has been limited to events and settings under DIYbio the movement. Based on the assumptions that imagination of soft impacts plays (or should play) a role in improving the quality of ethical debates on emerging technologies (made by Swierstra (2015a)) and that imaginative moral reasoning is better than rule-governed reasoning (according to theories of moral imagination in moral philosophy), I assume for the purpose of research that evaluating the imaginative potential of the kit will be sufficient to analyze its role in enriching ethical discussions on CRISPR.

[1] http://www.the-odin.com/diy-crispr-kit/

Thus, I address the question: **Can DIY-CRISPR kit enrich the ethical deliberation and evaluation of CRISPR technology by stimulating imagination? If so how?** Throughout this thesis, especially in the evaluation of DIY-CRISPR, my assumption is that triggering moral imagination is necessary and sufficient for stimulating the 'imagination' that Swierstra argues as required for anticipating soft impacts. However, moral imagination stimulates reflections about hard impacts as well. I further break down my research question into the following sub-questions that will act as a guide to the investigation:

- What is CRISPR? What are the current ethical discussions surrounding CRISPR technology?
- What is DIYbio? What are the ethical discussions surrounding DIYbio movement?
- What is the role of imagination in ethical deliberation, especially with in the context of ethics of emerging technology?

These sub-questions are dealt with individually in each of the following three chapters. The reading guide described next illustrates this point.

READING GUIDE

Following this introductory chapter, in Chapter II, I will give a detailed description of the genome editing technology of CRISPR by reviewing scientific literature, media articles and advisory reports that talks about the technology over the past five years (2013-2018). Firstly, I will describe the technology and its working. This will be followed by enumerating the speculated applications of the technology. Then, I will discuss the risks and challenges presented by CRISPR which prevents translation of the current research into clinical applications. Thereafter, the pattern of ethical arguments posed against and in favor of the technology will be mapped using NEST ethics developed by Swierstra (2015b). After introducing and discussing the concepts of 'soft' and 'hard' impacts, I then analyze the quality of the ethical debates on CRISPR by looking at the type of arguments and discussions that are common in the ethical discourses relating to the technology.

In Chapter III, I will first introduce the DIY-CRISPR kit and the different discussions surrounding it. In the sections following, I will describe in detail the DIYbio movement and ethical concerns in relation to the movement to give the reader an understanding of the context in which the kit is embedded. Furthermore, I also define and discuss the role of bioart in the ethical discussions concerning biotechnology. Works of authors like Vaage (2016) and Holmberg &

Ideland (2016), compares bioart to "materialized visualization of the futures" and "imagination laboratories." This finding is then used as a reason to examine the potential of the DIY-CRISPR kit in stimulating imagination and enriching ethical debates. In this chapter, in addition to scientific sources and reports I also rely on insights from my informational and user experience interviews with experts and users of the kit.

In chapter IV, I review the theory of moral imagination and imaginative moral reasoning using the accounts of contemporary pragmatists such as Mark Johnson, Steven Fesmire, Mark Coeckelbergh and moral sentiment theorist Martha Nussbaum. Based on the roles of imagination described in moral philosophy, I then develop a criterion to evaluate if the DIY-CRISPR kit does and can stimulate moral imagination. I investigate the conceptual and contextual framing of the kit along with the character of textual materials (like its story-like structure) associated with the kit during the evaluation. After discussing the results of the evaluation, I suggest an alteration/addition that may be made to the kit in order to improve its imaginative potential and thereby, increase its chances of being used in technological assessment contexts of CRISPR.

In chapter V, I will summarize my findings and arguments. Finally, I will also state the limitations of my research and provide suggestions for future research.

METHODOLOGY

In this thesis, I conducted both theoretical research in the form of literature reviews and empirical research in the forms of interviews. For the theoretical sections within the thesis, especially for chapter I, II and initial sections of III, I relied on different literature sources such as scientific articles, advisory reports, online blog entries and website pages (to get information about the kit and also information about different DIYbio community labs and workshops). For analyzing the use of the kit, I also watched few YouTube videos which showed how the users conducted the experiment in the kit and their opinions about it. Since, academic discourses on the DIYbio movement were limited, I conducted informational interviews with five experts to gain insight about different aspects of this niche movement. For instance, I got to know about different workshops in which the kit has been used and about the different issues that were raised during such workshops through the experts who either participated or organized such a workshop.

Besides informational interviews, I also interviewed users of the kit ("user experience interviews"). During the interviews with three users of the kit, I enquired about their reasons for

buying the kit and their opinion following its use. Both the interviews conducted were semi-structured. I had received approval (request number 18614) from the Ethics Committee for Behavioral Sciences for conducting these interviews on June 4, 2018. I took verbal consent from the experts and users prior to recording the interviews. I also have written consent from the experts saying that I can use their names for the purposes of this thesis in association with their interview responses. Furthermore, each of the experts received a draft of the chapters in which their comments were mentioned for revision and verification (to clarify if any misinterpretation occurred). The responses of the users, on the hand, has been anonymized as 2 out of the 3 interviewees preferred anonymity. All empirical data that has been collected will be deleted soon after the thesis is published. This step is in accordance with the recently established GDPR rules.

THE GENOME EDITING TECHNOLOGY OF CRISPR-CAS9

1. INTRODUCTION

Clustered regularly interspaced short palindromic repeats(CRISPR) is a genome editing tool that has gained the attention of scientists, geneticists, sociologists and ethicists around the globe. CRISPR technique, also referred to as CRISPR-Cas9, in combination with the DNA cutting enzyme Cas 9 (CRISPR associated protein), according to scientists and pioneers of the field Doudna & Charpentier (2014, p.1077) is a low cost easy-to-use technology that can be used to "precisely and efficiently target, edit, modify, regulate, and mark genomic loci of a wide array of cells and organisms." According to Doudna & Charpentier (2014), the emergence of this 'facile' genome editing tool has prompted a 'revolution' globally as scientists in laboratories around the world have begun to employ the technology for innovative applications in biology. CRISPR technology is predicted to have applications in the field of agriculture, synthetic biology, biological research and human medicine (Caplan, Parent, Shen, & Plunkett, 2015; Doudna & Charpentier, 2014).

Using scientific papers which describe the functioning of CRISPR technology, review articles that emphasize and discuss the ethical issues of CRISPR published between 2013-2018 and advisory reports for policy making at national/ international level (such as the report on germline editing by COGEM and Health Council of the Netherlands) as literature sources, this chapter provides an overview of the discussions and debates surrounding CRISPR-Cas9 technology. In the following section (Section 2), CRISPR technology along with its applications and benefits will be briefly introduced. In Section 3, the limitations and risks posed by the gene editing technology will be elaborated. The ethical concerns posed in relation to CRISPR will be reviewed using the NEST ethics approach in Section 4. In this section the regulatory measures adopted by different institutions and countries will also be discussed. Following this in Section 5, an analysis of the ethical debates on CRISPR will be made in addition to providing a brief introduction to the concepts of soft and hard impacts. Moreover in Section 5, I will argue that the quality of the current ethical deliberations on CRISPR-Cas9 technology is poor and less

imaginative due to the lack of weight given to soft impacts in the ethical debates relating to CRISPR technology. Finally, concluding remarks would be made in Section 6.

2. CRISPR-CAS9 TECHNOLOGY

Making site-specific modifications to genomes of organisms has been a dream goal of researchers and clinicians since the discovery of the DNA's double helix structure (Doudna & Charpentier, 2014). Initially identified and believed to be 'junk' DNA by Japanese researchers in the genome of *Escherichia coli* in 1987, the functionality of a series of short direct repeats interspaced with short sequences was only studied in detail after 2005, when the plasmid/viral origins of the spacer sequences within CRISPR were observed by microbiologists (Doudna & Charpentier, 2014). CRISPR-Cas systems, the adaptive defense mechanism employed by bacteria and archaea against bacteriophages and viruses, function by storing/ integrating specific DNA sequences of the virus and plasmid, during primary attack, to the proximal end of bacterial(host) CRISPR array(Jinek et al., 2012). During a subsequent infection or the interference phase, these DNA sequences are transcribed into RNA which search for the specific sequence in the invading virus and cleaves off the desired sequence using the DNA-cutting enzyme known as Cas 9. The virus DNA spacer which gets integrated into the CRISPR array, hence, remains dormant until further attack from a virus (see Fig.1).

Based on this finding of the CRISPR mediated immune response in bacteria, scientists like Jennifer Doudna and Emanuelle Charpentier developed CRISPR-Cas9 systems that can cut or suppress the functioning of a specific segment of the DNA. Doudna & Charpentier (2014), based on their study of DNA targeting activity in *Streptococcus pyogenes* bacteria, identified that engineering the guide RNA(gRNA)[2] according to the DNA sequence that needs to be modified would program the Cas9 enzyme to cleave at the desired location within the genome of the organism. This two-component system of consisting of engineered gRNA and Cas9 protein, as they argue, allows for precise and efficient cutting of the DNA strands. Injecting the cells undergoing modification with this system along with a sample gene (in form of a RNA strand, hence, would facilitate the insertion of a new gene at the broken site in the genome. Thus, as described in the COGEM & Gezondheidsraad (2017, p.22) report, CRISPR-Cas technology is the

[2] Guide RNA(gRNA) is dual RNA structure composed of a mature CRISPR RNA(crRNA) that is base-paired to trans-activating crRNA (tracrRNA)(Jinek et al., 2012). This complex of tracrRNA: crRNA has a guide sequence to form base pairs with the target DNA sequence. This complex thereby guides the Cas 9 protein to "introduce a site-specific double-strand break in the DNA"(Doudna & Charpentier, 2014).

"biological version of 'search and replace' function in a word processor" which alters DNA by cutting, replacing or adding new genetic material (see Fig.2).

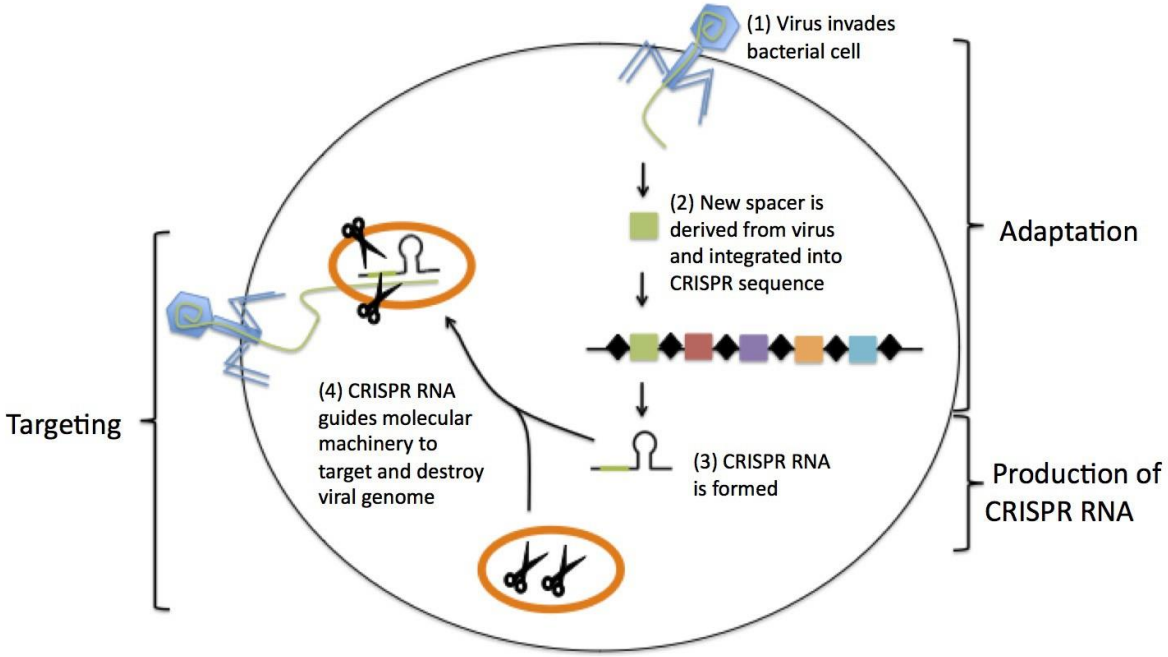

Fig 1. The development of adaptive defense mechanism in bacteria against viruses. The viral DNA is integrated into the CRISPR sequence of the bacteria during primary infection. Cas9 enzyme (represented by the scissor icon) cleaves the DNA of the virus at the location dictated by the CRISPR RNA sequence during subsequent viral infection (Pak, 2014).

CRISPR technology, however is not the first genome editing tool which is capable of modifying specific sections of the genome with precision. Globus & Qimron(2018) lists four engineered nucleases that have been widely used in genome engineering: meganucleases, Zinc finger nucleases (ZFNs), transcription activator-like effector nucleases (TALENs), and CRISPR-Cas9 and orthologs. CRISPR-Cas9 systems are considered to be versatile, easy to manufacture and inexpensive than the former three genome editing techniques as these are directed by proteins which have to be custom manufactured for different DNA targets(Reyes & Lanner, 2017).

Based on the theoretical understanding of how CRISPR technique allows for precise insertion, deletion, suppression of DNA sequences at any position in genome of multicellular and unicellular organisms, many authors discuss the following as probable application fields of CRISPR:

- Agriculture- CRISPR technology can be used in agriculture to improve food for human consumption as the technique would enable increasing the muscle mass of animals,

rendering farmed animals less prone to diseases, enhancing their nutritional content and producing hornless cattle that are easier to handle (Caplan et al., 2015; Ledford, 2015)

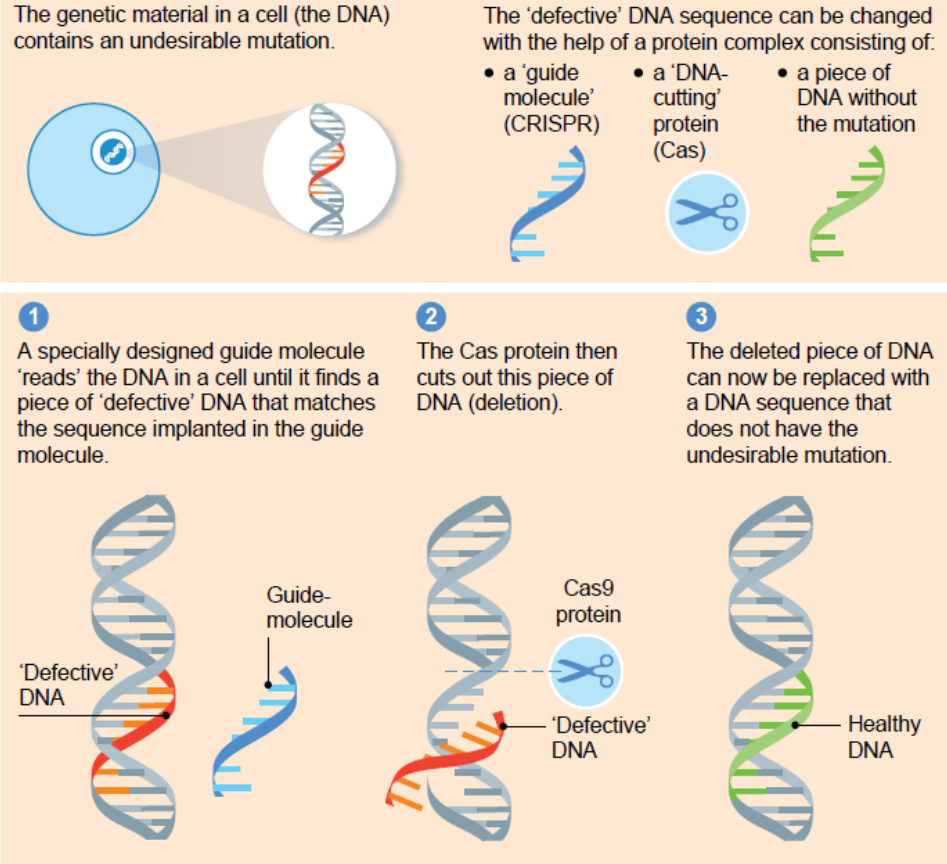

Fig 2. This infograph shows how CRISPR-Cas system can be used to correct a defective sequence within a genome (COGEM & Gezondheidsraad, 2017).

- Environmental engineering- Environmental engineering through the eradication of potential disease vectors and invasive species by a mechanism called gene drive, has been considered a potentially beneficial use of CRISPR-Cas9 technology by scientists such as Feng Zhang and George Church[3] (Caplan et al., 2015; Weidmann, 2018). Gene drive, put simply, is an experimental tool that allows for the edited trait to be passed onto the successive generations through sexual reproduction (Caplan et al., 2015). Unlike mechanisms in which the probability of the progeny having inherited the modified genes is 50%, when GM organisms released into the environment mate with wild-type organisms, in case of gene drives, mutation produced by CRISPR on one chromosome is actively copied onto the partner chromosome which thereby

[3] These are prominent researchers in the field of CRISPR-Cas technology.

"ensures that the offspring and the subsequent generations will inherit the edited genome"(Caplan et al., 2015, p.1422). According to Caplan et al. (2015), currently research is being conducted by biotech firms on the *Aedes aegypti* mosquito, which transmits dengue fever, and certain subspecies of the Anopheles mosquito that carry the *Plasmodium* parasite to prevent the disease transmission through modification of the female mosquito which renders it incapable of carrying the disease. Other methods such as making the male mosquitos sterile or limiting their lifespan through genome editing are also being tested.

- Human medicine- The medical and clinical scope of this genome editing technology, as predicted by scientists such as Lander (2015), include treatment of genetic diseases such as sickle cell anemia and Huntington's disease as well as non-genetic diseases such as HIV and Cancer. Hsu, Lander, & Zhang (2014), for instance, claims that the CRISPR-Cas9 system may be used to correct the causative mutation for genetic diseases like cystic fibrosis and Duchenne muscular dystrophy. Several experiments have been conducted so far to study the efficiency of CRISPR in therapeutic applications of treating diseases. Park (2016) highlighted that a group of researchers were able to remove the more than 50% of the HIV virus from the body of the retrovirus infected rats in 2015. Besides these therapeutic applications of CRISPR, speculations have been made about the use of the technique to create "genetically modified human" or "designer babies" which carry "permanent heritable changes to human germline DNA"(Lander, 2015, p.5). Such speculations regarding the potential use of CRISPR for enhancement applications shape the 'hype' surrounding the technology. As will be shown in the next sections, the current state-of-the-art of the technology has several technical and ethical challenges to overcome prior to its predicted use in clinical settings.

  Within the context of human embryo research, Reyes & Lanner (2017, p.4) argues that CRISPR technology can be used to study the "early regulatory events that shape embryonic development" by making use of it gene disruptor function. According to them, the knowledge obtained through this investigation of "how normal human pre-implantation development is controlled" is of great value in the treatment of infertility and in the field of stem cell- based regenerative medicine.
- Biotechnology and Synthetic biology- According to Caplan et al. (2015, p.1425) , CRISPR technique would be beneficial in the field of synthetic biology as it can be utilized in the synthesis of microorganisms suitable for applications such as "the production of

pharmaceuticals, biofuels, or chemicals to the remediation of pollution or disease diagnostics and treatment."

- Biological research- Within the field of genome research, Doudna & Charpentier (2014) argues that CRISPR-Cas9 technology can be used to develop disease models that would benefit the understanding of human diseases and pharmacological studies as it "provides a robust technology for studying genomic rearrangements and the developments and progression of cancers and other diseases"(p.4). According to Pennisi (2013) the creation of mouse and rat models for human diseases using CRISPR allows for studying the functions of individual genes and for quicker manipulation of multiple cells to understand their interactions.

3. RISKS AND TECHNICAL LIMITATIONS OF CRISPR-CAS9

CRISPR-Cas9 technique as discussed in the previous section is claimed to be beneficial for different applications fields ranging from basic biology to environmental engineering. However, many experts have indicated that state-of-the-art of CRISPR technology is far from the speculated hype of being used to cure diseases, prevent malaria and design babies with desired characteristics. Scientists and experts identify off-target effects[4] and mosaicism[5] produced as a result of CRISPR modification as two important technical challenges that needs to be mastered (Bosley et al., 2015). The technology, which still is in its early stage of development, has to overcome these technical barriers before it can be utilized to edit human genomes in clinical settings (Bosley et al., 2015; Lander, 2015). According to Baumann (2016), presently the technical feasibility of CRISPR technology to efficiently and precisely modify genomes is very low.

The use of CRISPR-Cas9 technology in human germline editing for therapeutic or enhancement reasons, creation of novel pathogenic organisms, environmental engineering and disease vector eradication, and in agriculture, according to experts like Johannes Rath (2018), raises safety and security risks. Rath (2018, p.108) defines 'safety' as the "protection of humans, animals, plants and the environment from unintentional harm" and 'security' as the protection of organisms and environment from intentional harm. In the context of human germline editing, he argues that the key safety concerns are in relation to off-target mutations, mosaicism and epigenetic

[4] Off- target effects are results of non-specific activity of the Cas nuclease in locations of genome that were not targeted. Since under such conditions another gene might be mutated, the effect or phenotype may be confused for the results expected of on-target mutation (Reyes & Lanner, 2017).

[5] Mosaicism occurs when the cells divide before genome modification takes place. The outcome of mosaicism is that either the daughter cells carry the edited sequence and display mutation or it will not carry it and remain unaltered.

effects produced as a result of the modification. These problems which lead to unpredictability and uncertainty regarding the consequences of the gene modification performed, Baumann (2016) argues, is the main safety issue with human germline editing. The security issue with germline editing is that the human enhancements could cause harm to other beings. The creation of novel pathogenic organisms or infectious disease models, from Rath's perspective raises the safety risks, as their accidental release could cause harm, and security risks as these organisms can be used for bio terroristic purposes. The safety concerns posed by the use of CRISPR for environmental engineering relate to "environmental harmfulness, controllability and reversibility of such environmental interventions" (p.110). While genome editing in agriculture, according to Rath raises the safety issues relating to "outbreeding and spread of these new varieties into natural populations, the detectability of these new variants and challenges to established coexistence provisions [of GM and non-GM organisms]" (p.110).

Thus as described in this section, CRISPR-Cas9 technology though full of promises has several challenges, that need to be overcome before the "bench to bedside" transition (Mulvihill et al., 2017). In the next section, ethical concerns raised by the potential use of CRISPR technology and regulations in place to ensure the proper use of the technology will be discussed.

4. ETHICAL CONCERNS & REGULATORY POLICIES

The promises made by CRISPR technology, specifically to cure genetic and non-genetic diseases, according to Jasanoff, Hurlbut & Saha (2015), are similar to that of recombinant DNA(rDNA) technology which altered the economic and social practices of biotechnology in the mid-1970s. Jasanoff et al. (2015) frames the relation between rDNA and CRISPR technology as "If rDNA techniques rewrote the book of life, making entire genomes readable, then CRISPR applies an editorial eye to the resulting book, searching for typos and other infelicities that mar the basic text." Just as in case of other emerging technologies, Mulvihill et al. (2017), noted that in discussions surrounding CRISPR's potential in clinical settings, the challenge is to separate hype from reality and distant possibilities from early applications. According to Mulvihill et al. (2017), though CRISPR raises similar ethical issues as those posed by genetic engineering 20years ago, this "disruptive" (Ledford, 2015) technology requires special attention since the technology by itself is capable of reducing the time required to perform experiments which previously took several years. In other words, Mulvihill et al. (2017) argues that the ethical concerns posed by

CRISPR must be addressed soon since the technology and its research in the field are progressing rapidly.

Based on the promises and limitations discussed in the previous sections, in the upcoming sub-sections a review of the arguments made in favor of and against the application of CRISPR technology to edit the somatic and germ cells in humans, plants and animals will be made in accordance to the NEST(New and Emerging Science and Technology) ethics outlined by Swierstra (2015b). Swierstra highlights that the ethical discussions which question the moral desirability of a NEST commonly revolve around the arguments relating to the consequences of the technology; just distribution of benefits and resources; rights, duties and responsibilities (deontological arguments) and the good life. In case of NEST, Swierstra (2015b) notes that consequentialist arguments typically take the form of positive or negative expectations about the future.

Under the following sub-section "Human Genome editing", I will describe the pattern of arguments posed by proponents and opponents to the potential use of CRISPR technique for editing germlines and somatic cells. Similarly, in the section of "Non- Human genome editing", I will discuss various claims, from consequentialist, deontological and good life (animal welfare) perspectives, that has been made in relation to the proposed application of CRISPR in agriculture and environmental engineering. In these sections I will also highlight the regulatory policies and measures adopted internationally and by different countries in relation to the particular ethical and safety concerns. Furthermore, I will briefly introduce the CRISPR patent battle in the "CRISPR-specific issue" section.

4.1 Human Genome Editing

4.1.1 Germline Editing

CRISPR-Cas9 technique has become popular amongst public because of its potential to correct heritable disease-inducing genes in human germline cells. In discourses concerning the potential application of CRISPR in germline editing of human embryos, proponents argue for the desirability of the same using the consequentialist argument that the technique would cure and/or prevent the occurrence of genetic diseases such as sickle cell anemia in future generations. This consequentialist argument which can be viewed as a hope or promise made by supporters of the technology to gain the acceptance has faced oppositions. One of the oppositions posed has been based on the arguments made in general against any technology that enables germline editing i.e

germline editing can permanently change the gene pool and alter the trajectory of genetic evolution across species(Hough & Ajetunmobi, 2017).

Opponents to the consequentialist argument in favor of CRISPR enabled human germline, have also questioned the plausibility of the speculated future, where genetic diseases can be cured, by referring to the current finding on the technical feasibility of the techniques. Lander (2015), geneticist and founding director of the Broad Institute[6], presented the technical issue that the current state-of-the-art of the technology cannot achieve precise and accurate editing as the first issue amongst the four key issues that he observed as human germline editing raises. The technical limitations of producing off-target effects and mosaicism associated with CRISPR, as described in Section 3, has been identified by Rath (2018) as responsible for the safety concerns in relation to human germline editing. Moreover, the safety issues raised by germline editing, according to Baumann (2016), have to do with the uncertainty regarding the consequences produced by germline editing which are unpredictable and may give rise to unintended side effects. These safety concerns, arising from the technical difficulties and the uncertainty associated with CRISPR edits, thus, have motivated many of the experts to adopt precautionary measures and call for a moratorium on human germline editing.

In a meeting convened by the National Academy of Sciences of the United States of America, the Institute of Medicine, the Chinese Academy of Sciences and the Royal Society of London in December of 2015, an international group of scientists after discussing the ethics of germline editing came to the agreement that basic research can proceed under proper legal and ethical guidelines while editing human gametocytes and embryos to produce inheritable changes will be regarded as irresponsible (E, 2016; Wade, 2015). This restriction on germline editing is in effect in many European countries, China and in USA, where the National Institute of Health has banned funded research on genomic editing of human embryos. This "self-imposed ban" /moratorium which urges for a temporary suspension of editing the human germline and conducting further research into the efficacy and specificity of CRISPR Cas9 systems, according to Guttinger (2017) and many other leading scientists, is modelled based on the precedent ban on recombinant DNA technology that was established at the Asilomar Conference held in 1975. Interestingly, many of the scientists who led the moratorium call on rDNA technology were also

[6] The Broad institute is a collaboration between MIT, Harvard, the Whitehead institute and affiliated hospitals. This group and Jennifer Doudna's group are involved in the patent battle for CRISPR technology.

involved in the CRISPR-CAS9 conference in 2015. Arguments by Guttinger(2017) and Jasanoff et al. (2015) contradict these scientists who consider that CRISPR technology can be regulated by the same decisions that were made in Asilomar. According to Guttinger (2017) the two step strategy that made the Asilomar ban on rDNA successful cannot be transferred to the case of CRISPR enabled germline editing as in case of CRISPR research the "processual nature of the organisms" is of importance, which was not a subject of discussion or study for rDNA[7]. Whereas according to Jasanoff et al. (2015), the "uncritical application of Asilomar model to CRISPR would do a disservice to history as well as democracy" as in the case of Asilomar the debates were too narrow with priority mainly given to scientific interests and assembled representatives, which mainly constituted of scientists from America, few from Europe and none from the developing world. Recently, researchers from UK and Sweden scientists received permission for conducting genetic modification on human embryos using CRISPR-Cas9, for research purposes only, from their respective authorities like the Human Fertilization and Embryology Authority (HFEA) in the UK(Reyes & Lanner, 2017). This research permission that has been granted, however, does not allow the scientists to implant the modified embryos and asks them to destroy the embryos following the 14-day rule.

Few authors and experts have discussed alternatives to germline editing human embryos for treating genetic diseases. According to Swierstra (2015b), suggesting such alternative options can be visualized as contestation of consequentialist arguments which are in favor of the technology. Like mentioned above, the main projected application for CRISPR germline editing is to prevent monogenic diseases such as Huntington's disease, cystic fibrosis and sickle cell anemia. However, authors such as Lander (2015) have suggested that upon closer inspection the reasoning behind adopting genetic modification of embryos to prevent such rare monogenic diseases disappears. There exist many other less controversial alternatives to germline editing.

[7] As Guttinger (2017) describes, the two step containment strategy of the Asilomar ban included 1) creating a separation between the use context and research context (or safe space) for rDNA technology and 2) experimenting to investigate the risks of rDNA technology in the created safe space. Following his analysis, Guttinger arrived at the conclusion that this two-step strategy cannot be applied to CRISPR as a safe space cannot be created to study the safety issues relating to the effects of a particular DNA modification made using CRISPR in embryos. This is mainly due to the reason that embryos, unlike the microbes that were the organisms of discussion in Asilomar ban, are ascribed a moral status and recognized by different stages in their developmental process. In case of human embryos used for gene editing research, beyond the physical containment within research labs, containment exists in terms of the stages of development that the organism is not allowed to leave, i.e based on the 14-day rule. Thus, the strategies of the Asilomar ban which does not take into account dual condition, of having a moral status and being processual in nature of human embryos, cannot be transferred to scenarios of CRISPR-Cas 9 germline editing.

Using PGD (pre-implantation genetic diagnosis) to identify the diseased embryos and implanting only the ones that are risk-free is one such option put forward by many experts. In situations where PGD is not applicable, such as in case of autosomal recessive diseases when both the parents are homozygous or autosomal dominant diseases when one of the parents is homozygous (Araki & Ishii, 2014 as cited in Baumann, 2016), the only alternatives to germline editing as Baumann argues is "choosing not have not to have a child, adoption and egg cell or sperm donation"(p.145). These options, nevertheless, are not favorable for those who wish to have a genetic child of their own.

Counterarguing the proponents by presenting alternatives to CRISPR germline editing reinforces the question of if the risks of performing germline editing (from the inaccurate edits or unintended effects of the edits) outweigh the current medical needs. This question was voiced by Lander (2015) as the second issue raised by human germline editing. This concern which requires the calculation of the risks and benefits, can be placed under the distributive justice-based arguments presented in the context of NEST as it is linked with the understanding of whether resources and time from a distribute justice perspective should be invested in CRISPR germline editing research. From the standpoint of many like Lander, investing in routine genetic testing is worthwhile as it would increase awareness amongst couples who did not know if they were at risk to avail PGD or make decisions regarding how to/whether to have a healthy child of their own rather than on CRISPR.

Another ethical and socio-economic concern posed by the potential use of CRISPR for germline editing, from a distributive justice standpoint, is that of just access. This issue of just access which is valid also for somatic editing, discussed in the next sub-section, deals with the question of who gets access to the CRISPR enabled mutation correction procedures and gene therapies. In most of the media and the scientific articles, the discussions regarding the cost of performing genome editing using CRISPR has been constant and emphasizes its inexpensiveness in comparison to other techniques such as TALENs or ZFNs. However, Baumann (2016) asserts that employing CRISPR technique beyond basic research, i.e. in clinical settings, may not be cheap as there are other technical, medical and economic factors that play an integral role in the final cost which in turn affects the accessibility to the therapy. Swierstra (2015b) in his discussion of NEST ethics, highlights the view held by proponents of the technology regarding the "trickle-

down effect"[8] that eventually balances out the initial unequal access to a new technology. In case of CRISPR germline/somatic therapy, according to Baumann (2016), assuming that the trickle-down effect argument is valid as any other NEST is incorrect. The reason for this, she argues, is that the price of biologically derived therapeutics (like those that would be enabled by CRISPR) would not decrease significantly in the long run "as there are no generic drugs in this sector" and companies other than the initial developers of the therapy cannot copy the production methodology or lower the costs (p.146). Hence, as Caplan et al. (2015, p.1425) remarked, supplementing existing cell based therapies such as stem cell treatments, which are considerably costly, with CRISPR enabled gene therapies would only increase the price and thereby, make it a private luxury that cannot be benefitted by "those with average means and insurance,… who are uninsured, destitute, or rely on national health services to decide what is to be made available to patients."

The third issue raised by germline editing, according to Lander (2015), is with regard to the question of "who has the right to decide" about the modifications made to the embryo. This issue is referred to as the problem of intergenerational consent (Sugarman, 2015). Under NEST ethics, the issue of intergenerational consent is identified as part of the deontological arguments raised against the technology. This issue is of deontological relevance as germline editing using CRISPR technique can violate the autonomy of the embryo (or future person) that will have its genome edited based on the consent from his/her parents. This autonomy-based consent concerns are not new as they have been discussed vividly in the past in relation to the topic of enhancement through genetic engineering (cf. Habermas, 2003). In case of CRISPR too, there have been claims made regarding using germline editing in a hypothetical distant future to enhance certain traits such as intelligence and athletic prowess of the offspring (also referred to as 'designer babies') according to the preferences given by the parents. Proponents of the germline manipulation for non-health related reasons such as philosopher and bioethicist Julian Savulescu, employ the "argument of precedence" to argue that banning germline interventions would be illogical as we already use technologies that impact future generations and have always relied upon parental decisions regarding where to educate one's child, what clothes' to buy and what diet to be followed that (could) limit the potential child's options later in life (Savulescu et al. as cited in Hough & Ajetunmobi, 2017; Schaefer, Kahane, & Savulescu, 2014).

[8] According to the concept of trickle-down effect, first only the wealthy can benefit from the technology due to its high prices and later after the prices fall, it would become accessible to the poor.

Another deontological concern that has been raised by this potential application of CRISPR has been with regard to the threat it poses to human dignity. In ethical discussions and articles relating to CRISPR research on human germline editing, the issue concerning human dignity is framed in terms of arguments that either advocate or oppose the consideration of embryo's moral status. Experts and legislators around the world occupy different positions in the debate of "if a human embryo should be accepted as human from the moment of its conception" (Rolf, 2012, p. 742). Those who consider that the *in vitro* embryo has a moral status, as it has the potential to grow into an individual, protest against germline manipulations and urge for the embryo's right to protection, similar to a newborn child (COGEM & Gezondheidsraad, 2017). This recognition of the moral status of embryos has given rise to debates regarding the creation of embryos for scientific research purposes. In the Netherlands, for instance, culturing embryos for research is prohibited while the use of surplus embryos, i.e. embryos that remain unused following assisted reproduction treatment, for scientific study is allowed. Since it has been observed that surplus embryos are not ideal for all types of research, in 2016, the Dutch government announced their plan to revise the Embryo Act in order to permit culturing of embryos for research (COGEM & Gezondheidsraad, 2017). As opposed to the Netherlands and Germany, in the UK, "generation of human embryos for research purposes, the cloning of human embryos, and the creation of admixed human-animal embryos for research" is permissible under the renewed Human Embryology and Fertilisation Act in 2008 (Rolf, 2012, p. 743). In contrast, Rolf (2012) highlights that according to this British Act, which appears to be influenced by Utilitarianism and its aim of improving public happiness and benefit, the embryo during its first two weeks of conception is regarded as a 'pre-embryo'(and not as a proper embryo) which is ethically accepted for use in research. But after 14th day, when the primitive streak appears, and the embryo is assumed to be able to feel pain, the legislation states that the embryo should not be used for implantation or further research and that it must be destroyed. Thus, this 14-day restriction assumes that becoming human is a gradual process that is marked by the appearance of the primitive streak on the 14th day and so, human dignity is not relevant in the initial 13 days.

In case of germline interventions using CRISPR, good life arguments are rarely discussed separate from the other rule-ethical arguments that have been explained above. As Swierstra (2015b) notes, questions in relation to good life, are dismissed as private concern in general ethical discourses. However, in terms of the two good life ethics issues defined by Swierstra, namely

boundaries and control, oppositions to human germline editing have been in the context of CRISPR. These claims which counter any sort of genetic interventions refers genetic engineering as trying to "play God". By referring to the technology as allowing to "play god" what opponents mean is that the technology gives you power to destroy fixed boundaries (say between species) and to exert control over others with this power. According to supporters of such a claim, by editing genes, for curing disease or enhancement, scientists are trying to control a 'natural' process by 'unnatural' means (Chan, n.d.). The two main good life based arguments posed with respect to gene editing viz. "sanctity of life" and "playing God" are often discussed in relation to non-human genome editing and so, a detailed description of the same will be made in 4.2 Non-Human Genome editing.

4.1.2 Somatic Editing

The often-speculated potential for CRISPR technology to cure non-genetic diseases such as cancer and HIV seems to be one of the reasons for the wide popularity of the genome editing technology amongst the public. In the reviewed literature, the number of ethical issues raised by the potential clinical use of CRISPR for such therapeutic applications, in which the gene modification that is performed (in somatic cells) does not get passed on to the future offspring, appears to be negligible in comparison to those concerns posed in relation to the potential use of CRISPR to edit germ cells. As Rodriguez E (2016) states, this may be due to the general consideration of somatic genome editing as ethically acceptable by many including scientists and ethicists. According to E (2016), in such genomic alterations, informed consent can be obtained easily and there is a balance between risks and benefits.

However, few authors have raised the question of which diseases are the 'right' diseases to be researched upon for developing a treatment therapy. This question is of ethical relevance as it deals with the distribution of costs, in terms of research funding, and benefits, in terms of who receives the cure/treatment. This is again a distributive justice related argument according to Swierstra's (2015) NEST ethics. Baumann (2016, p.146) by referring to Cox, Platt, & Zhang's(2015) claim regarding which type of diseases can be treated successfully by somatic therapy, namely, "monogenic, highly penetrant diseases, such as severe combined immunodeficiency (SCID), haemophilia and certain enzyme deficiencies", argues that a careful examination and comparison needs to be made between the existing technology and potential CRISPR technique for every disease in order to determine if the resources in the form of research funding are allocated

justly. Baumann (2016) observed that initiatives which develop gene therapies for complex, chronic and multi-factorial diseases, such as cancer that affects millions of people acquire large proportions of the research funds than those that focus on monogenic diseases, which are comparatively easier to develop treatments for. Hence, she deduces that the criterion for deciding "which diseases need to be cured", so far, has been based on the number of people that will benefit from the cure.

4.2 Non-Human Genome Editing

Besides the ethical issues raised by human genome editing, as discussed above, the application of CRISPR to non-human organisms such as animals, plants, insects and microorganisms has been a matter of concern and worry amongst ethicists and scholars (Caplan et al., 2015). According to Schultz-Bergin (2018), a philosopher focusing on animal ethics, the attention given to the ethics of using CRISPR to engineer non-human animals and to the expansion of the "CRISPR-zoo" by philosophers and scientists is comparatively lower than that paid to human genome editing. Though few, the ethical discussions on non-human genome editing using CRISPR, are mostly centered around the consequences of generating and releasing genetically modified organisms(GMOs). Moreover, very few articles, explore the problems of genome editing on animal welfare.

The 'intrinsic'[9] objection to genetic engineering, as Schultz-Bergin (2018) argues, stem from deontological and virtue ethics related notion that species boundaries are "divinely or naturally established"(Robert & Baylis,2003 as cited in Schultz-Bergin, 2018) and should not be transgressed by the unnatural techniques developed by human beings. This intrinsic objection which is relevant for genome editing techniques that use foreign DNA (from another species) to modify the DNA of the host organism is, however, not applicable to CRISPR enabled genome modification, as CRISPR makes use of its "natural DNA repair pathway to alter genetic information" (Schultz-Bergin, 2018, p.223). This technicality of CRISPR technology, wherein there is no crossing of species boundaries involved, has therefore allowed CRISPRed organisms to bypass certain regulatory policies consider GMOs to be transgenic (or having the DNA of another species). In USA, the Coordinated Framework consisting of the Food and Drug Administration(FDA), the US Department of Agriculture(USDA), and the Environmental

[9] According to Schultz-Bergin (2018) "intrinsic objections to a technology aim to establish the impermissibility of using the technology regardless of the consequences."

Protection Agency (EPA), have issued guidelines in relation to agricultural application of genome editing with regulations that cover only plants pests like animals, bacteria and fungi which would damage the crops directly or indirectly (Caplan et al., 2015). These regulations can be applied only when the pest DNA or viral vectors are inserted into a host organism, which is not the case in CRISPR genome editing. As Caplan et al. (2015) notes, contrarily in the EU, all sorts of genetic modification is considered transgenic whether a foreign DNA was inserted or not. Thus, extensive risk assessment is conducted for each GMO and presented to the European Commission(EC) by European Food Safety Agency(EFSA) for approval or rejection of its use in the EU.

Another issue that has been raised against the generation of GMOs relates to the security risk due to genetic modification of microorganisms like bacteria and viruses using CRISPR. According to authors such as Caplan et al. (2015) and Rath (2018), CRISPR could be used to easily create novel pathogenic organisms or to increase the potency of dangerous pathogens by anyone with appropriate equipment and wrong intentions. Though such claims can be identified as part of the "slippery slope" and the "dual use of research" arguments against CRISPR research, i.e. encouraging development of disease-curing applications of CRISPR now will lead to CRISPR being used for bioterrorism/ biowarfare in the future, these biosecurity related concerns are being taken into account globally as serious. An example of a global action taken with regard to ensuring biosecurity is the internationally established Biological Weapons Convention(BWC) that came into force in 1972 which prohibits the research and production of biological weapons.

Gene drives, as discussed in the Section 2, is a CRISPR enabled tool that can be used to control populations of disease carrying species such as mosquitos that spread malaria. Objections to research and testing of gene drives, as Pugh (2016) describes, are based on the ethical ideologies of "sanctity of life" and "playing god." According to the "sanctity of life" principle, the decimation of another species, which is projected as a probable consequence of releasing the CRISPR-edited organism into the wild, is intrinsically wrong. While the "playing god" ideology argues that using gene drives to eradicate mosquitoes represent the "unacceptable degrees of hubris" of humankind (Pugh, 2016). Such ethical discussions concerning gene drives currently occur independent of the ethical discussions on CRISPR. However, the issue relating to the accidental release of GMOs or CRISPRed organism is a subject of fear and debate in both the discussions due to the uncertainty of the consequences. Caplan et al. (2015), hence, argues for the development of global regulations that would monitor the testing and release of GMOs.

Schultz-Bergin (2018) in his article "Is CRISPR an Ethical Game-Changer?" presents argument both in favor and against the genome editing of animals using CRISPR from an animal welfare perspective. Taking into consideration the typical animal welfare indicators of "mental well-being, physical health, and engagement in species-typical behaviors" Schultz-Bergin focuses on the potential consequences that CRISPR genome editing could have to the animal itself (p.227). According to his analysis, the versatile and cheap nature of CRISPR technology is both beneficial and harmful to animals as i) it increases the number and variety of animals that are used for gene-editing research, which in turn raises the chances for animal suffering and research failures that could have detrimental effects on the animals, and ii) it "opens new avenues to pursue engineering projects that are aimed at improving animal welfare"(p.234). Thus, in Schultz-Bergin's opinion, CRISPR technology brings novel ethical concerns relating to ethics of animal use and welfare to the fore while trying to replace existing agricultural and research practices that are focused on improving productivity and ignorant about animal suffering.

4.3 CRISPR-Specific Issue

A "CRISPR-specific" issue, as Globus & Qimron(2018) frames it, concerns the intellectual property(IP) rights to CRISPR-Cas9 technology. The CRISPR patent battle between the Broad Institute of Cambridge, Massachusetts and the team of research institute including University of California, Berkeley began in 2014 when the Zhang group(Broad Institute) was awarded the U.S. patent for editing eukaryotic cells with CRISPR-Cas9 by the U.S. Patent and Trademark Office (USPTO) even though the Doudna-Charpentiar team (UC Berkeley) had applied for CRISPR patent long before than Zhang's group (Ledford, 2017). In 2016, the legal team advocating for UC Berkeley filed for an "interference" proceeding to determine the original inventor of CRISPR-Cas9 genome editing technology("History," n.d.). Finally, on September 10, 2018 the US court of Appeals for Federal Circuit awarded the patent rights to the Broad Institute (Ledford, 2018).

This issue of intellectual property raised in relation CRISPR is ethically problematic from a distributive justice perspective. According to Mulvihill et al. (2017, p.9),the principle of 'solidarity' and public good, or the "mutual sharing of costs and dividends, burdens and benefits, and not just in economic terms", is necessary between those developing the technology and those affected by it. Hence, in their opinion, the whole idea that a powerful technology like CRISPR-Cas9, which was discovered as bacteria's defense mechanism, can be patented and owned by a

researcher (and institution) is obstructive to the solidarity principle as patency could deny people's "access to its [the technology's] benefits outside market mechanisms" (p.9).

5. DISCUSSION

In the above section, a review of the arguments that constitute the current ethical discussion on CRISPR technology was made using the NEST ethics ordering developed by Swierstra (2015b). As can be observed, most of the arguments posed are in relation to the consequences(harm) of performing genetic engineering using CRISPR to values like the environment, health and safety. According to Swierstra & te Molder (2012, p. 1059), such dominant claims(especially ones related to consequences and distributive justice elaborated in Section 4) qualify as 'hard impacts' of a technology as they refer to "indubitable instances of harm…[to values such as] Safety, Health, Sustainability, Privacy, Profit, and Employment," which can be quantified in numerical or economic terms and explained causally. These "objective, rational, neutral and factual" concerns dominate the public arena discussions relating to emerging technologies as opposed to 'soft impacts'(Swierstra & te Molder, 2012, p. 1052). 'Soft impacts' refer to the moral implications on relations, identities, norms and values associated with the introduction of new technologies (Kiran, Oudshoorn, & Verbeek, 2015). In ethics, van der Burg(2009) argues, soft impacts can be placed under the field of moral psychology as they deal with the effects of technology on the human perception, experience, habit, motivations and ways of relating to other organisms. From a virtue ethics perspective, these concerns, hence, have the potential to shape the people's understanding of good life and how (and if) they can live a good life using the technology (van der Burg, 2009).

Authors such as Kiran et al. (2015) and Swierstra & te Molder (2012), based on their observation of Risk assessments(RA) and Technology Assessments(TA) conducted on emerging technologies, pointed out the lack of concerns relating to the soft implications of new technologies in such public deliberations. Soft impacts share similarities with the good life arguments posed in relation to NEST as they too are often considered to be "irrelevant or a private issue" that does not require serious attention (Swierstra & te Molder, 2012). The reasons for dismissal of soft impacts by technologists and policy makers can be attributed to its characteristic of being unquantifiable difficult to anticipate and morally ambiguous in comparison to the hard impacts. These reasons, in Swierstra & te Molder's opinion, must not stop scholars from trying to explore the plausible alterations the introduction of a new technology can bring to the structure of norms and relations

within a context[10] and to the moral landscape[11]. Though difficult to predict, Swierstra (2015a), argues that "thick description or narratives" such as stories are good vehicles for invoking soft impacts and making them present for anticipatory reflection. Hence, anticipation of soft impacts usually take the form of "vignettes offering snapshots of possible future practices, or scenarios describing how current practices are destabilized under the influence of technologies, and how they may evolve in response to these technological challenges"(Swierstra, 2015a, p.14). To help one imagine such plausible scenarios/stories relating to the future soft impacts of a technology, Swierstra urges for investigation into "how our moral perception and action in world are mediated by technology," which informs one of the "recurring patterns of technomoral change" (p.14).

According to Swierstra (2015a), with technological societies becoming affluent and concerned about human flourishing beyond fulfilment of basic needs, and new technologies becoming 'intimate' by entering our life-world space, 'soft impacts' are currently being recognized and discussed as part of the public agendas. The mains reasons for urging to consider soft impacts in discussions relating to emerging technology, as Swierstra & te Molder (2012) delineate, are i) it provides a fair hearing to concerns of citizens regarding the technology even if the concerns are not 'hard' (this makes the deliberation more democratic), ii) it helps to improve the technologies and iii) the anticipation of user's behavior changes due to the introduction of the new technology will be useful in preparing for the possible resistance or unintended use to/of the technology in the future and for taking appropriate actions to prevent such resistance/use.

In the context of CRISPR-Cas9 genome editing technology, the soft impacts, as hinted earlier, are not given sufficient attention as hard impacts. Concerns about soft impacts such as how would CRISPR enabled genome editing of future generation change our conception of 'care'? Would we regard children as manufactured goods?(Lander, 2015), How would curing genetic impairments such as blindness change the identity of the disabled in the society? If germline editing is the new norm, can parents be held responsible for not editing their child? Would CRISPRed food be regarded as "natural" by consumers? are barely raised and discussed in the articles and public discussions relating to CRISPR. The 'sanctity of life' and 'playing God' arguments, posed against the whole field of genetic engineering more than two decades ago, are

[10] Referred to as short-term soft impact of technology in Kiran, Oudshoorn, & Verbeek(2015)
[11] Referred to as long-term soft impact of technology in Kiran, Oudshoorn, & Verbeek(2015)

still the only soft concerns[12] that are dominant in CRISPR discourses as well. Thus, it can be argued that the quality of ethical debate relating to the introduction and development of CRISPR technology is poor and short-sighted due to the lack of discussion on the soft impacts of the technology.

6. CONCLUSION

The acclaimed "revolutionary" and "controversial" genome editing technology of CRISPR-Cas9 was the main subject of discussion in this chapter. The CRISPR-Cas9 systems, which were first observed in bacteria as a defense mechanism against viral infections, according to many scientists, allows to make precise edits in specific DNA locations in a simple and cheap manner. The majority of literature sources highlight the potential applications of CRISPR in the fields of synthetic biology, agriculture and medicine. Though full of promises about potential benefits such as preventing genetic diseases (cystic fibrosis) and curing non-genetic diseases(cancer) in human beings, CRISPR faces many technical limitations and, poses safety and security concerns. In addition to these, several ethical and societal concerns have been raised against the use of CRISPR to edit human and non-human genomes. However, the general ethical discussion on CRISPR, as reviewed in the chapter, appears to be focused on the hard impacts of CRISPR rather than on the soft impacts. As these debates on CRISPR have failed to take into account the moral implications of the technology on our values, identities and relation to others, I argue that the quality of deliberation is poor and less imaginative.

By using this argument as the reason to explore ways to improve CRISPR deliberations, I will investigate in the following chapters if (and how) the DIY-CRISPR kit can stimulate imagination about the soft impacts of introducing and developing CRISPR-Cas9 genome editing technology. In the next chapter, the DIY-CRISPR kit under study in this thesis will described along with an overview of the history of DIYbio movement and the ethical discussions surrounding it. I will also discuss the role of bioart in raising soft concerns in this chapter.

[12] Soft concerns, as I refer to here and in following chapters, are concerns about soft impacts. This term has been used by Swierstra & te Molder (2012) in their article on "Risks and Soft Impacts" where they discuss how soft concerns manifest in patient deliberations about a future pill for celiac disease and how such concerns are often dismissed in public-expert interactions.

THE DIY-CRISPR KIT & DO-IT-YOURSELF BIOLOGY MOVEMENT

1. INTRODUCTION

Over the past three decades, biotechnological activities have increasingly been performed outside scientific and corporate institutions like university laboratories and research institutes. These activities which are commonly referred to as “kitchen biology”, “garage biology”, “biohacking” and “bioart” fall under the global phenomenon of Do-it-Yourself Biology(DIYbio). The DIYbio movement along with the DIY-CRISPR kit, supplied by the biohacking company the ODIN, will be the main focus of discussion in this chapter. Besides published scientific articles and press reports on the movement and the kit, in this chapter, interview responses of five experts in the field of DIYbio and bioart, and three users of the DIY-CRISPR kit will used as relevant sources of information.

The five experts, two of whom I got to know from the attending the *Science Frictions* workshop and symposium organized at University of Twente, other three from literature and media references were selected for the interviews as they seemed to offer different perspectives on the DIYbio movement, based on their different expertise and backgrounds. Following experts were the interviewees for the informational interviews:

- Agnieszka Anna Wolodzko, art philosophy researcher and coordinator of AKI BIO MATTERS (artistic research program at AKI Academy of Art & Design).
- Lucas Evers, the head of Waag’s Open Wetlab, Amsterdam.
- Nora S. Vaage, assistant professor of philosophy specialized in art and culture.
- Pieter van Boheemen, researcher at Rathenau Institute and former head of Open Wetlab, Open Design Lab and Fablab Amsterdam at Waag.
- Roland van Dierendonck, coordinator and teacher of Waag’s BioHack Academy.

For the user experience interviews, I got in contact with interviewees through a message I posted on the members forum of the DIYbio.org network and on a Facebook group called Biohacking and Genetic Design Network asking for individuals who are willing to share their experience of

using the ODIN's DIY-CRISPR kit. Three of my interviewees are those that responded to this post. All of them have different academic backgrounds and interests.

In the upcoming section, i.e. Section 2, a detailed discussion of the ODIN's DIY-CRISPR kit and the ethical concerns posed in relation to it will be made using information gathered from blog posts about the kit, the product page in the ODIN website and expert and user interviews. Following this, in Section 3, an introduction to the DIYbio movement in terms of its definition, characteristics, its main sources of inspiration from past movements, activities that are conducted and members of the DIYbio groups will be provided. In Section 4, the ethical discussions surrounding the DIYbio movement and the different regulatory measures adopted to prevent the raised biosafety and biosecurity concerns, as described in various reports and articles, will be reviewed. In the same section, the relation between bioart and bioethics will also be described. Finally, the chapter will be summarized in Section 5.

2. THE ODIN's DIY-CRISPR KIT

Do-It-Yourself Kits, designed either for self-diagnostic or educational purposes, have been associated with the citizen science and DIY movement as it allowed the public to learn more about their body, the surroundings and other organisms in the environment. One such kit is the DIY Bacterial Gene Engineering CRISPR Kit (will be referred to as DIY-CRISPR kit henceforth) which is manufactured and supplied by The ODIN (Open Discovery Institute). This DIY bacterial CRISPR kit along with DIY Yeast Gene Engineering CRISPR kit was part of a crowdfunding campaign that Josiah Zayner, biohacker and CEO of The ODIN, ran on Indiegogo platform in 2015 under the name "DIY CRISPR Kits, Learn Modern Science By Doing" (Zayner, 2015). The campaign was a huge success that it raised $71000, seven times more than the actual goal, which led to Zayner quitting his job in NASA to run the ODIN full time (Yin, 2016). The ODIN website currently offers numerous gene engineering kits like the Fluorescent Yeast kit and the Frog Genetic Engineering kit, a recent addition. According to Zayner, offering the resources needed to biohack at home through such kits at an affordable price allows for the 'democratization of science' as it increases people's accessibility science (Krieger, 2016).

Fig 3. Image showing the different components of the DIY-CRISPR kit used in the ODIN webpage for the product ("DIY Bacterial Gene Engineering CRISPR Kit," n.d.).

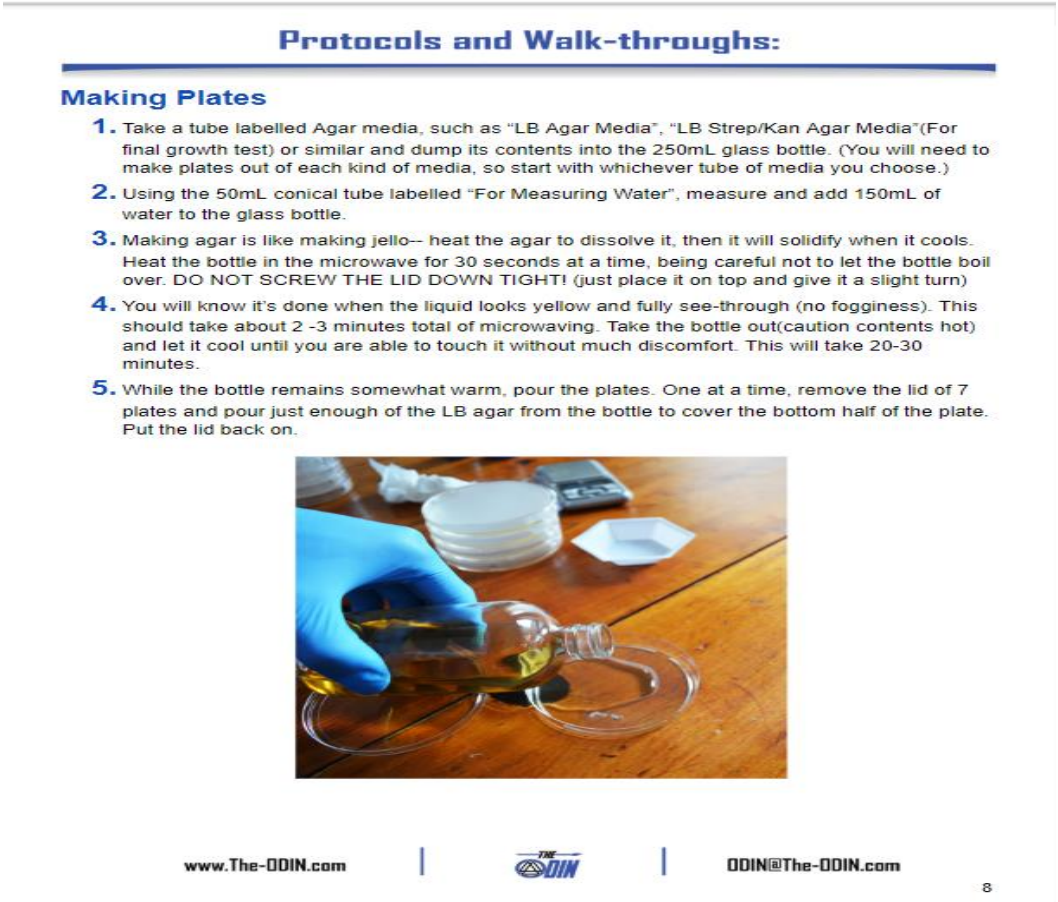

Fig 4. This image shows as an example the layout of the protocol for conducting the experiment. The instructions shown here are for making agar plates ("CRISPR Bacterial Guide," n.d.).

2.1 Structure, Purpose and Use of the DIY-CRISPR Kit

The DIY-CRISPR kit which is purchasable from the ODIN website for $159 consists of all the equipment and materials such as the Cas9 plasmid, *E.coli* bacteria, template DNA, microcentrifuge tubes and volume adjustable pipette required to modify the bacteria so that it can grow on a Streptomycin medium, which otherwise prevents bacterial growth ("DIY Bacterial Gene Engineering CRISPR Kit," n.d.; Sneed, 2017). The main aim of the experiment within the kit is to modify the bacterial genome. A protocol (shown in Fig 4) with few pictorial walk-throughs that instructs what to do with the supplied materials to perform the CRISPR genome editing comes with the kit. The protocol consists of step-by-step instructions on i) how to make agar plates for growing the bacteria, ii) how to make the bacteria 'competent' so that it can take in foreign DNA and iii) how to transform (or modify the genome) it using the supplied Cas9 plasmid, gRNA plasmid and template DNA. In the digital version of the protocol, additional google documents explaining how to use the pipette and how to streak out bacteria or yeast on agar plates are attached.

The opinion of my interviewees regarding the protocol for experiment were mixed. According to all the three of the interviewed users and one of the experts, the instructions stated in the protocol are "amateurish," "complex" and "poorly documented with few errors" that "it does not make the topic[CRISPR] approachable to someone who is not already competent in the topic." Tarantola, (2016) and Sneed (2017), two writers who reported their experience with using the kit on online magazines that discuss developments in science and technology, referred to the protocol as similar to recipe instructions in a cookbook. In contrast to such negative opinions, many of the product reviewers on the product page of the ODIN, except for one who called the protocol as "confusing" and "wordy", described the instructions as easy to understand and thorough. Roland van Dierendonck, for instance, expressed that by following the manual closely in the context of a workshop one can "understand or get an impression of how CRISPR works" without being informed about "how to set up one's own CRISPR experiment" (personal communication, July 5, 2018). These opinions, hence, are indicative of the basicness of the experiment and the kit. It also implies that everyone can the use the kit including those with no experience in biotechnology, something that Zayner promised in his campaign.

Furthermore, the number of experimental trials conducted to achieve successful gene modification (indicated by growth of whitish or yellowish bacterial colonies on the streptomycin medium) varied across the interviewees. For instance, it took five tries for one of the users to

complete the experiment successfully. Whereas another user, a bioengineering student, remarked that he got the expected results in the first trial itself. This, in his opinion, is rare in science. Regarding the success rates, Pieter van Boheemen argued that it is highly likely (almost 90%) that someone with no previous experience in biotechnology will fail to perform the experiment and achieve the results as contaminations are bound to occur if the user isn't careful and precise in each step (personal communication June 21, 2018).

The intended purpose of the kit, as Zayner indicated in his Indiegogo campaign, is for learning science by 'doing'. The product description, for instance, states that the example experiment "teaches you many molecular biology and gene engineering techniques"("DIY Bacterial Gene Engineering CRISPR Kit," n.d.). Most of the interviewed users too ascribed a pedagogic role to the kit. According to them, the kit serves as an educational tool to learn the basics of CRISPR genome editing technology. However, Zayner's discussions in Biohack events and videos, seem to imply that the purpose of the kit is to open science to the public.Agnieszka Wolodzko in agreement of this purpose commented that the "purpose of the kit is to break the boundaries of science and make its[science's] relation to the society more egalitarian" (personal communication June 14, 2018). Reflecting on the reasons for people buying and using the kit, Nora Vaage stressed that different groups of people have different agendas and interests behind buying the kits. She illustrated this point by stating that there are many who order the kit like a board game to tinker and play around for fun, hence as a hobbyist option, while there are some artists that take this kit to professional labs as it is easy and simple (personal communication June 11, 2018). Vaage commented that "when your [as an artist or biologist] aim is not to create the most specific experiments with the lowest failure rates" then the kit is a good option and "works quite well". Another reason for buying the kit, as expressed by one of users, was because his children enjoyed the fruit DNA extraction experiment that they performed previously and wanted something more advanced.

As an educational tool, the DIY-CRISPR kit has been used widely in many collective settings such as DIYbio community lab workshops and events. In the Biohack Academy that was organized by Waag's Open Wetlab from January to April 2018, during a special workshop on CRISPR, the participants were guided by van Dierendonck to follow to the steps mentioned in the protocol. Genetic engineering conducted without appropriate permission and supervision is punishable in the Netherlands. Hence, the final step of bacterial transformation (introducing the

plasmid into the bacteria via a heat shock) was not performed during this workshop as it was outside the genetic modifications the Open Wetlab is permitted to conduct and a biosafety officer was not present to supervise the event. However, important ethical questions like should such a modification be made because it is possible or because it is for educational purposes and not for art were raised during the event (van Wetering, 2018).

2.2 Ethical Debates

Most of the ethical discussions associated with the kit has been in relation to biosafety and biosecurity. One of the initial biosafety concerns was posed by Todd Kuiken, a senior program associate at the Woodrow Wilson Center. Kuiken (2016) argued that the kit failed to meet the biosafety protocols as dictated under the DIYbio.org code of conduct. He criticized Zayner's "disregard for basic biosafety protocols" based on a video segment that showed petri dishes stored next to food in a fridge(as cited in Yin, 2016). His criticism however, seems to be more directed at Zayner for setting a bad example for amateur DIYbiologists than on the kit itself. Many biohackers and ethicists have been worried about this cavalier attitude of Zayner towards safety procedures. Especially after Zayner live-streamed injecting humself DNA that encodes for muscle enhancement concerns related to self-experimentation have been raised. Experts like Vaage and van Boheemen consider such stunts by Zayner as an advertisement for upcoming products and a "performance art", respectively, which spurs certain ethical discussions.

Biosafety concerns posed in relation to the kit, specifically, have to do with the fear about allowing laymen unregulated access to a powerful technology like CRISPR. Whereas the biosecurity concerns are based on the conception that people with nefarious intentions may use the kit to develop bioweapons. The detection of potentially pathogenic bacteria belonging to risk group 2 in the kits by the Bavarian Bureau of Health and Food Security posed a biosafety issue (Chardonnet, 2017). Following the discovery of pathogenic *E.coli*, the Bureau warned DIYers in Germany against the use of the kits and informed the ODIN regarding the contamination since Zayner specifically had assured that the "bacteria are less harmful than the bacteria on your skin" on the campaign page. The ODIN responded to the authorities by claiming that the contamination could have occurred at any point between the time of shipment and analysis.

Based on the interviews that were organized with three users and five experts who used DIY-CRISPR kit under different contexts, it was observed that most of them have a positive attitude towards the kit. All of them emphasized the role of the kit in simplifying the complex

technique of CRISPR and genetic engineering. This simplification of the whole process by the kit, though useful in terms of developing an interest in CRISPR amongst DIYers, according to experts like Vaage and van Dierendonck, gives the false impression that genetic engineering is very easy (personal communication June 11 & July 5, 2018). Having acknowledged that the kit is very basic and limited in terms of what can be done using the kit (i.e.it does not teach one how to setup a CRISPR experiment kit), many of the interviewees stressed the importance of the kit in expanding their interests to explore further by acting as a starter kit and in creating awareness about genome editing through its pedagogical use as well as through the controversial performances of Zayner.

Having made a brief overview of the DIY-CRISPR kit and the discussions surrounding it, in the upcoming section I will discuss and review the DIYbio movement and the ethical debates around it to position the kit in the broader context of this movement.

3. DO-IT-YOURSELF BIOLOGY(DIYBIO) MOVEMENT

The Do-It-Yourself Biology movement, commonly known as 'DIYbio' ever since the inception of the DIYbio.org website by Jason Bobe and Mackenzie Cowell in 2008, is a worldwide phenomenon in which amateurs, students, hobbyists, scientists, artists and designers are engaged in activities relating to biology and biological materials outside of scientific institutions. The DIYbio movement, as Pieter van Boheemen described during the interview, can be defined based on the context and intentions behind the practices and activity. According to him, contextually, DIYbio movement is doing biotechnology outside the "mega-structure of science" and "formal context", while based on the intentions behind activities, DIYbio is engaging with biotechnological activities not "necessarily with the intention of creating new knowledge or starting business" but "for fun, personal interest or to provoke discussion" (personal communication, June 21, 2018). The main features that characterize DIYbio, as outlined by Seyfried, Pei, & Schmidt (2014, p.548), are: "(a) Interdisciplinarity b) Primarily a not-for-profit endeavor c) Design and use of cost effective tools and equipment (d) Focus on open source and open science innovation, thus positioning itself as an alternative to so called "Big Bio" [13] (e) Democratization and self-empowerment as the biggest difference to conventional research activities."

[13] What is referred to as "Big Bio" are academic-industrial research complexes that consist of "million-dollar universities", governmental research institutions and corporate labs where scientific research is presumed to be conducted (Keulartz & van den Belt, 2016). According to Keulartz & van den Belt (2016) the business models of DIYbio and the Big Bio are entirely opposite. Big Bio's research in their opinion is "highly profit driven" and focused

Though the DIYbio movement has gained popularity through media articles since the "Splice it Yourself" article on *WIRED* by biologist Rob Carlson (2005) where he announces "The era of garage biology is upon us", according to sociologist Morgan Meyer (2014) the movement has a much older history. In his opinion four related movements have influenced the current DIYbio movement, namely, i) the DIY movement that emerged in the 1950s relating to home improvement and fashion ii) the open source movement of 1990s iii) the hacker movement in the domain of software and computer and iv) the development of synthetic biology and associated student competition of iGEM(International Genetically Engineered Machine) . The link between synthetic biology, iGEM and the DIYbio movement has been mapped by many other authors, such as Ledford (2010) and Landrain, Meyer, Perez, & Sussan (2013). The modularization and standardization techniques which were developed by synthetic biology to make "biology easier to engineer", commonly referred to as 'de-skilling'[14], presented amateurs with the image of biology as something that can be easily engineered and as a means to attain better knowledge of their environment, their health and their bodies (Landrain et al., 2013, p. 116 ; Vaage, 2017). In the iGEM competition, that has been annually conducted since 2003, student teams have to create synthetic systems that would work in living organisms. This competition, since then, has served as a meeting spot for different biology enthusiasts and future founders of various DIYbio community labs and groups (Keulartz & van den Belt, 2016). Thus, as Ledford (2010) remarked the DIYbio movement picked up both "stigma and momentum" from the field of synthetic biology.

The influence of the hacker movement on DIYbio is evident from the fact that the DIYbio movement has adopted the general principles of the hacker ethic, viz. "improving access, sharing, collaboration, decentralization, free access to computers or tech, and world improvement," to increase the "openness, availability and accessibility" of biology to the broader public that is currently limited to university researchers (Levy, 1984 as cited in Keulartz & van den Belt, 2016 ; Meyer, 2014). These goals of the DIYbio movement are drawn out in Meredith Patterson's, *Biopunk Manifesto*. Patterson is an American technologist and "the 'doyenne' of DIY-Bio" (Keulartz & van den Belt, 2016, p.6). Her manifesto highlights the need for "scientific literacy" in

on "economic productivity" (p.3) unlike the DIYbio movement. Also "Big Bio is responsive to big companies" and DIYbio to the community.

[14] De-skilling in the context of synthetic biology does not imply any "lay person can design and produce organisms that behave predictably and reliably" without adequate scientific skill, but that the standardization and mechanization processes developed as part of the field of synthetic biology eliminate the need for depending on highly trained individuals during the production process(Jefferson, Lentzos, & Marris, 2014).

the modern world. She also outlines the responsibilities of biohackers to be "emissaries of science" and urges for respecting the living organisms they use in research, as well as the communities which may or may not be affected by their experiments (Patterson, 2010). According to Patterson's manifesto, a scientifically literate person "can *do* science" while a scientifically educated person understands science.

The aspect of 'doing' biology is often referred to as biohacking in the domain of DIYbio movement. In this context of DIYbio, what is meant with hacking is different from the common negative interpretation of hacking as breaking down computers or doing something illegal. Hacking as defined by Levy(1984) is equivalent to tinkering which involves "taking things apart, seeing how they work, and using this knowledge to create new and interesting things" and thereby learn how the system and world works(as cited in Keulartz & van den Belt, 2016, p.6). Most of the hands-on activities that take place in the DIYbio community labs are of this nature. According to Landrain et al. (2013), DIYbio practitioners are engaged in designing and redesigning scientific equipment and protocols. Ledford (2010, p.) argues that such activities which open up biology by providing accessible and affordable alternatives to expensive scientific instruments and methods are "creative proof of the hacker principle." Authors, Landrain et al. (2013) and Keulartz & van den Belt (2016, p.2), claim that biohacking practices have the capacity to foster new scientific practices and thereby, can be identified as a "new way of doing science." Besides such hacking projects, most of the DIYbio groups conduct member-led seminars, workshops and guest lectures to educate their members about biotechnology and its recent developments (Landrain et al., 2013).

Though initially the DIYbio movement became popular as "kitchen biology" (Wolinsky, 2009) or "garage biology"(Carlson, 2005) based on the claim that biology can be done at homes with household items, these days most of the activities take place in dedicated community labs. According to a survey conducted by Grushkin, Kuiken, & Millet (2014), amongst 305 DIYbio practitioners around the world only 8 percent responded as working at home while the remaining said they conducted DIYbio activities in groups spaces like hacker spaces or community labs. Early DIYbio community labs include GenSpace in New York, Biocurious in California and La Paillasse in Paris (Landrain et al., 2013; Seyfried et al., 2014). In the Netherlands, the Waag Society in Amsterdam hosts an active Open Wetlab community. The community lab headed by Lucas Evers and supported by a multidisciplinary team of artists and biologists including Roland van Dierendonck organizes different workshops, meet-ups and academies to educate individuals

to “build their own lab, create bio experiments, and get into the basics of synthetic biology and practice critical reflection”(Waag, n.d.). Since, the majority of lab equipment required to do simple experiments are expensive, setting up a community lab by pooling in resources seems to be a feasible option for biology enthusiasts and amateurs who otherwise don’t have access to such facilities (Landrain et al., 2013; Vaage, 2017). According to van Dierendonck, “having a space or providing a platform to perform activities where people can do research and work with others” is an important objective of community labs such as the Open Wetlab in Waag (personal communication, July 5, 2018).

Having described the general source of motivation behind the DIYbio movement, the question of who the members of this worldwide community are can be posed. Broadly, anyone with an interest in biology and life sciences can be a member of the DIYbio community. Members of DIYbio activities include designers, artists, students, hobbyists, engineers, scientists and researchers. As Landrain et al.(2013) notes DIYbio communities do not require its members to have academic degrees. However, Grushkin, et al.'s (2013) survey showed that the majority (19% have doctorate level degree, 27% masters and 37% completed college) of DIY community is more educated than the general population.

Thus, as sketched in this section, DIYbio movement is a worldwide phenomenon in which amateurs, artists, students and experts pursue the field of biology through tinkering practices outside of scientific institutions in community labs, hackerspaces, garages or kitchens. The motive of the movement often is to increase the openness, accessibility and availability of biology to the public.

4. ETHICS AND REGULATIONS ON DIYBIO MOVEMENT

With the growth of the DIYbio movement worldwide and advancements in the field of synthetic biology and genetic engineering, fears associated with the potential danger of biohacking practices conducted in community labs, homes and garages have only increased over the past decade. Ethical discussions, primarily of two kinds, are associated with the DIYbio movement. The first kind of ethical discussions concern the relocation of scientific and technological practices by DIYbio to outside scientific institutions, while the second type of ethical discussions relate to questions raised regarding the ethical and social implications of particular technologies and practices. The former type, deals with ethical concerns often raised by actors external to DIYbio movement, while the latter deals with ethical issues raised during activities or workshops by actors/members within

movement. Most of the articles on DIYbio have focused on the first type of ethical issues rather than on the latter. In this section a brief review of both types of ethical problems posed regarding the DIYbio movement and the regulatory policies that have been adopted will be made.

The biosafety and biosecurity concerns voiced against the whole DIYbio movement for using engineering techniques and technologies in contexts outside professional academic laboratories and institutions are the main issues debated under the first type ethical discussions on DIYbio movement. Seyfried et al. (2014, p.548), without much further discussion, emphasizes that DIYbio raises issues in the "areas of research safety, the safety of potential products, risk to public health and environment, dual use research issues (biosecurity) and the ethical and social implications of the projects." The biosafety risks which are given more weight in Europe than in US, in the context of DIYbio, are often associated with the pathogenicity of the organisms used or accidental release of the products of experimentation that may be pathogenic (Grushkin, et al., 2013).On the other hand, biosecurity concerns raised against DIYbio movement are based on the fear that biohackers can design bioweapons for bio terroristic purposes and thereby, cause intentional harm to people. However, many authors have argued that these biosecurity fears are unfounded. Landrain et al.(2013, p.124) debunks the claims made by those who believe that the de-skilling made possible by synthetic biology allows the easy design of bioweapons using arguments such as "living organisms are too complex to be entirely captured by such an abstraction[technique in synthetic biology]" and "[I]t is indeed much more easy to spoil a genetic function than to optimize it, especially in the case of virulence." He highlights the need for "sophisticated tacit knowledge on experimental biology" to create pathogens (p.124). Moreover, Grushkin et al. (2013) challenged the myth that "DIYers are capable of unleashing a deadly epidemic" based on his survey results which showed that most of the DIYers work with BSL 1(Biosafety level) microorganisms that are non-pathogenic. In relation to these concerns Jason Bobe, founder of DIYbio.org, and Ellen Jorgensen, co-founder of GenSpace, commented that press and people "overestimate biohackers' technological capabilities and underestimate their ethics" (as cited in Landrain et al., 2013, p.124 & Grushkin, et al.2013).

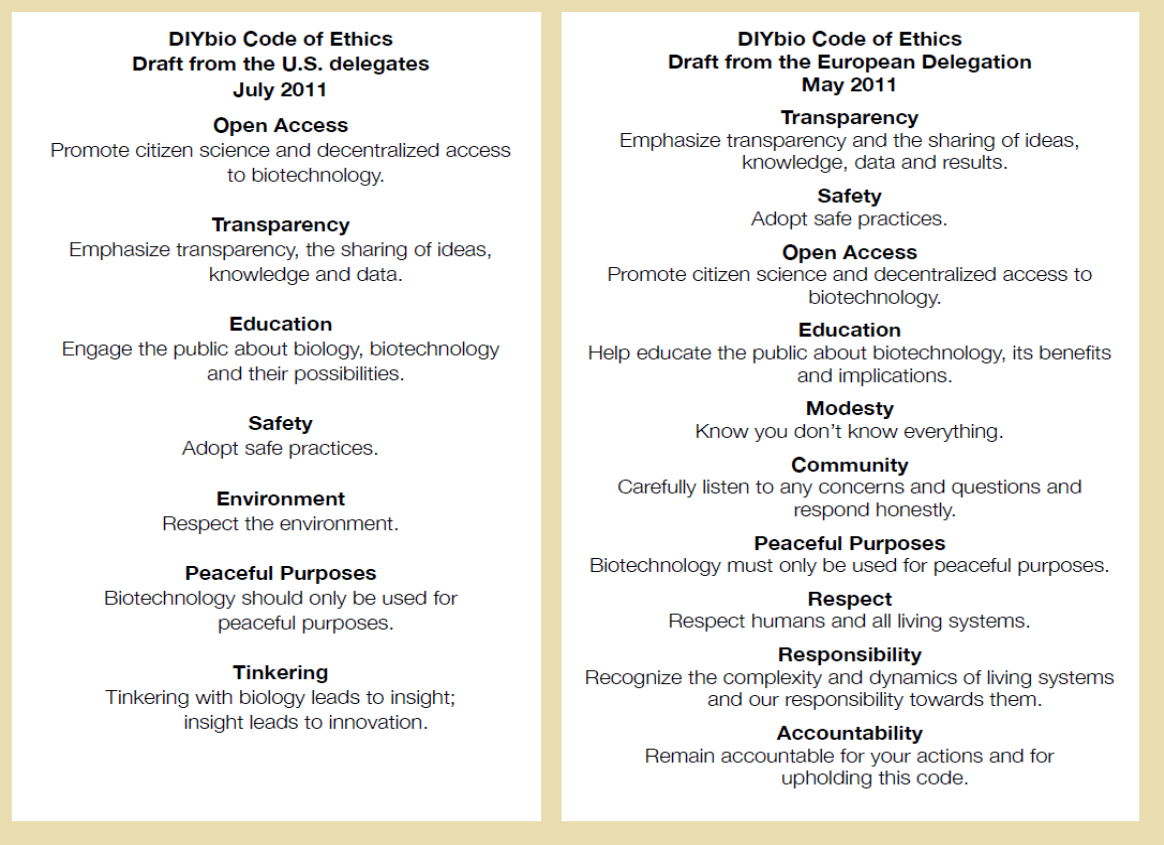

Fig 5. The DIYbio Code of Ethics drafted by the US and European delegates was developed in response to the biosecurity and biosafety concerns raised against the DIYbio movement (Grushkin et al.,2013)

The DIYbio community, according to Kuiken (2013), proactively addresses these security and safety concerns themselves, while those concerned push for governmental oversight into the DIYbio practices. Meyer (2014) identifies three types of responses made by the DIYbio community to these concerns. The first response, as already mentioned above, is with regard to the assurance that DIYers do not use dangerous materials and reiteration that to cause intentional harm one does not require DIYbio. Secondly, the DIYbio.org, along with the Wilson Center and delegates from the DIYbio communities from US and Europe, developed codes of ethics (as shown in the fig.5) to "help strengthen the culture of responsibility burgeoning in DIYbio" (Grushkin, et al., 2013, p.16). The third response was more practical. The DIYbio.org, in collaboration with the Woodrow Wilson International Center for Scholars, set up the "Ask a Biosafety Expert" portal through which anyone could ask questions relating to safety to a panel of professionals (Tod Kuiken, 2013).

Besides these initiatives from the side of DIYbio community multiple regulatory measures have been instituted to prevent any biosafety and biosecurity related dangers. For instance,

companies such as Twist Biosciences that manufactures synthetic DNA for its commercial customers have adopted screening policies such as vetting customers and checking the requested DNA sequence against the database of harmful organisms to safeguard DIYers from working with pathogens (Kirksey, 2016). Though there might not be formalized checks on DIYers and their activities, as Grushkin, et al.(2013) notes, regulatory checks in the form of safety level requirements for setting up DIY laboratories do exist. In the US, in 2010, a report by the Presidential Commission for the Study of Bioethical Issues stated that no additional oversight bodies were required to monitor the synthetic biology related activities of DIY scientists. Since then, the FBI has established friendly relations with DIY community labs like GenSpace and accepted the "neighborhood watch style" for monitoring DIY activities (Blazeski, 2014). In Europe, where regulatory policies concerning biosafety and genetic engineering are stricter, DIYbio groups need to acquire permits for performing genome editing related activities along with a certified lab status (Keulartz & van den Belt, 2016). In the Netherlands a special license is required to do genetic engineering. The Waag's Open Wetlab obtained an "S-I" license in 2015, which came with very strict safety regulations. This permitted the organization to create GMOs using a specific method that were known not to pose health risks in the presence of an independent biosafety officer (Waag, 2015).

The second type of ethical discussions relating to the DIYbio movement concerns the ethical questions and issues that are raised during workshops and events organized as part of the DIYbio movement. These discussions are mostly with regard to the ethical and social implications of the technologies and the practices adopted during the event. On this subject, Vaage commented that in workshops conducted by DIYbio groups, deliberations that occur are quite pertinent for understanding and assessing emerging technologies (personal communication June 11, 2018). Keulartz & van den Belt (2016) argue that the hands-on imperative of the DIYbio opens up the debate for issues that haven't been studied or raised by ethicists and public. To illustrate their claim, they gave the example of the "DIY In Vitro meat" workshop, organized at Waag's Open Wetlab, which opened up an interesting debate on *in vitro* meat. The participants of the workshop grew meat using mice stem cells. As Keulartz & van den Belt gathered from Lucas Evers, a lot of ethical and social questions were raised during the workshop in relation to both the use of mice stem cells and the acceptability of cultured meat. Some of the questions included "is 'test-tube meat' a natural product - 'real meat' -, or is it artificial, 'soulless meat'? Will cultured meat alienate

us further from nature and from animals? Wouldn't it be better if we changed our behavior? Does dependence on a technological solution amount to moral laziness?"(Keulartz & van den Belt, 2016, p.11).

Thus, as many of the interviewed experts confirmed, the activities performed under the DIYbio movement along with the discussions about novel ethical issues that accompany such activities can play a significant role in enriching the ethical debates concerning the technology, be it synthetic biology or CRISPR. The ethical issues raised during DIYbio activities, hence, are very similar to what Swierstra & te Molder (2012) refer to as soft concerns or concerns about the implications of technological introduction on our identities, lifestyle and relationships (see the questions posed in relation to *in vitro* meat above). However, these issues within the setting of DIYbio activities seem to be of less relevance in the academic literature relating to the movement. Majority of the sources pay attention to the biosafety and biosecurity concerns (or hard impacts) than to the second type of ethical and social discussions which occur during DIYbio events.

In the following sub-section, I will describe the activity of bioart and its role in biotechnological discussions. Bioart and bioartistic practices are a categorized as an activity under the DIYbio movement. Unlike the general discussion on other DIYbio activities, discourses on bioart emphasize the role of bioartworks in raising questions and issues beyond the usual safety and security concerns through stimulating imagination.

4.1 Bioethics and Bioart

The term bioart, initially coined by artist Eduardo Kac in 1997, refers to artworks created by using biomaterials such as tissue, blood or genes as medium and/or by biotechnological processes. In comparison to the US, the number of DIYbio communities which collaborate with artists and designers to create bioart is higher amongst DIYbio groups across Europe. Be it Stelarc's *Third Ear*[15] or Eduardo Kac's transgenic GFP(Green Fluorescent Protein) bunny[16], bioartistic projects have been controversial both within and outside the art community (Zylinska, 2009). According to Anna Dumitriu (2017), the lead artist in the European project *Trust me , I am an Artist*, artists when engaged in scientific research have the potential to critically question and explore a particular

[15] Stelarc is a famous performance artist. One of his works is the Third Ear, wherein he had an ear grown in vitro surgically attached to his left arm.

[16] Eduardo Kacis is an American artist well known for his bioart pieces. He created the transgenic GFP bunny(and called it Alba) by using the GFP gene found in the jellyfish, Aequorea victoria, that fluoresces green when exposed to blue light (A. Bureaud, 2005).

field, like the life sciences, by combining the "aesthetic sensibilities, such as beauty or disgust, with intellectual complexity"(p.83). Bioart, as Andrews(2007) argues, can serve as a guide to public policy by exposing the gaps in the regulations, the risks associated with the technologies and the cultural and social values that might be affected through the application of a technology. Another role of bioart, discussed by new media scholar Joanna Zylinska(2009), is that of educating the public about science through demystifying not just the technology, but also the different financial interests and investments that shape the biotechnology industry. She defines the engagement of artists with biotechnology as a "pedagogic process", in which artists partake in "theoretical and practical self-education" in order to inform the public by means of instructions on materials being used and their function.

Bioart raises a range of questions which are usually discussed under the domain of bioethics. As authors like Vaage (2016) and Zylinska (2009, p.17) have discussed, what is referred to as "bioethics" has changed from its definition as the "study of ethical dimensions of medicine and the biological sciences."[17] Lately, experts and scholars have begun recognizing bioethics as a discipline that also deals with philosophical questions regarding the constitution of boundaries such as of human/non-human and human life/death and not just concerned with developing and implementing regulatory frameworks for the treatment of living materials in scientific and technological contexts. The typical ethical concerns raised against bioartists and their works revolves around the questions like: should living materials be treated in a specific way, should artists be allowed to meddle with life, do they have the right to modify a living organism, and are they responsible enough to do so? According to Zylinska (2014, p.192, emphasis in original), such enquiries, though relevant, are not " *the best questions* we can ask about bioart…as they evoke a normative position on life." Zylinska argues that bioart projects are capable of challenging the "traditional humanist value-based ethics" (2014, p.194), which holds "human life" as a value in advance, by raising ontological questions of "what counts as human life? How are the boundaries of the human established and maintained? Is the distinction between humans, animals, and machines solid or arbitrary?" (2009, p.159). Furthermore, Zylinska (2009, p.158) emphasizes that bioartists and their artworks are in a unique position when posing such questions as they can

[17] This definition of "bioethics" was given by Warren Reich, the editor of the four volume Encyclopedia of Bioethics.

circulate these bioethical concerns in a "poetic"[18] manner without being subjected to the pressure of innovation and economic growth faced by scientists within biotechnology.

Bioart projects, hence, as Wolodzko described, have an important role in ethical discussions as they pose questions that ethicists do not know how to ask, and scientists are afraid to ask as it would hinder them in conducting a particular research (personal communication June 21, 2018). Zylinska (2009, p.162), for instance refers to artworks by Adam Zaretsky[19] as "bioethics in action." Zaretsky's performance at the Lowlands festival in 2009, where visitors were invited to inject zebra fish with chloroplasts as part of BioSolar Cells project, according to Keulartz & van den Belt (2016) serves as proof to the label given by Zylinska. This performance made the audience think about the consequences of their actions and led to questions such as "Are artists allowed to use such a technique even though they pursue other objectives than scientists? Is this technique not too farfetched and would it not be much more logical to reduce consumption? What will happen to the global economy if humans become sustainable through sunlight alone?" being voiced. These questions and issues raised in relation to bioart are similar to the concerns about the societal and ethical implications of a new technique or technology (or soft concerns).

According to Keulartz & van den Belt (2016, p.12), the ethical questions raised by Zaretsky's project can be classified as a type of "noncommittal futurist ethics," which are similar to the 'if-then ethics' explained by Alfred Nordmann (2007). They argue that this bioartistic practice and experience "stimulates imagination to speculative flights into a remote future" (p.12). Along similar lines, Vaage (2016, p.100) by referring to philosopher Nordmann's idea that one can be prepared for the future by observing present conditions, concludes that bioart projects like that of *Pig Wings* by TC&A(Tissue culture and Art) "materialize possibilities in our present that simultaneously carry visions for the future and show our technical and ethical limitations." Thus, in her opinion, living artworks through providing materialized visualizations of the potential capabilities and issues of existing technology (and regulations) can be considered as a type of "material technology assessment, with an expanded license to speculate" (p.100).

The role of bioart in contributing to the existing biotechnological debates, besides raising biosafety, biosecurity or dignity of the living materials related issues, has been studied by

[18] What Zylinska(2009) means by "poetic" is based on Heidegger's *poièsis* which refers to the technological process of bringing forth.

[19] Adam Zaretsky is a famous bioartist well known for his provocative bioart pieces. He was a student of Eduardo Kac, the creator of GFP bunny.

sociologists Tora Holmberg & Malin Ideland (2016). They build a framework based on Jane Bennett's notion of enchantment, to show that bioart projects have the potential to awaken responses and encourage sense-making activities amongst the audience that "go beyond the reductionist rational logics of established politico-moral discourses, such as cost-benefit calculations" (p.452). Holmberg & Ideland argue that genetic artworks can be considered as "imagination laboratories" wherein "un-framing and rupturing of contemporary rationalities [such as boundary distinctions] are facilitated" (p.448). By discerning what type of affects are mobilized by the art (wonder, fear, disgust); what type of forms are used in the artwork (hybridity, ordinariness) and what ethical responses are enacted (protection, rejection, inclusion), they claim that bioart can be identified as imagination laboratories that produce ethical questions beyond the usual 'choreographed' debate. Holmberg & Ideland validates this claim by analyzing three bioart projects. Eduardo Kac's art piece, the "plantimal" referred to as *Edunia*, was one amongst the studied artworks. The *Edunia* is a genetic hybrid of the petunia flower and Kac, with red veins that is representative of Kac's DNA. According to the authors, this artwork, which is a crossing of human and plant, evokes wonder (an affect) amongst its audience through its familiarity and ordinariness (form) and creates an ethical response of inclusion, protection of other species and problematizes "the notion of humanness and life" (p.460). Thus, bioart like *Edunia* challenge boundaries and categories of human/animal/plant and life/non-life and initiate bioethical discussions, different from the cost-benefit debates.

Based on the discussion made above about bioart and the type of bioethical questions that can potentially raises, I infer that bioart and bioartistic practices can bring forth concerns about the soft impacts of the technology for discussion in the public. The ability of bioart to evoke imagination and ethical response by means of mobilizing affects based on the type of form used, hence, can be of enriching value in ethical debates on emerging technologies.

5. CONCLUSION

According to user opinions, the DIY-CRISPR kit, which is a product of the DIYbio movement, is a simple, basic, educational tool to learn about the genome editing technology of CRISPR. In collective settings of DIYbio workshops and bioart events, this kit has been used with the intention of learning about the technology and discussing its future implications. The DIYbio movement, as described in this chapter, is a growing global phenomenon in which researchers, amateurs, students and hobbyists "do" science outside the traditional scientific institutions. The main aim of the

movement and its participants is to democratize and demystify life sciences by making technologies, equipment and materials affordable, available and accessible to anyone who is curious about science. Through the hands-on imperative promoted by DIYbio movement, authors van Boheemen & de Vriend(2014) argue, DIYbio practices have the potential to add value to social and ethical reflections on technology and life sciences. However, the ethical discourses relating to the movement and the DIY-CRISPR kit seem to focus on the biosafety and biosecurity risk (or hard impacts) that arise due to performing biotechnological experiments like genome editing outside scientific institutions. Discussions about the ethical concerns raised from within the movement during workshops and events seem to be absent in the literature about the movement. Based on the questions and issues raised in events such as the Biohack Academy and in the "DIY In Vitro meat" workshop, it can be argued that the concerns posed are about the soft impacts of the technology or technique under discussion.

The role of DIYbio in discerning and assessing the social and ethical impacts of emerging biotechnologies is commonly discussed within the domain of bioart. Bioart, referred to as "imagination laboratories" and "materialized visualizations of futures" by authors Holmberg & Ideland (2016) and Vaage(2016) respectively, has the potential to raise different ethical questions beyond the common cost-benefit and biosafety debates. For instance, by challenging the boundaries of human/non-human and living/nonliving they evoke a special ethical response. Bioart, hence, has the potential to stimulate imagination and questioning about the societal and ethical implications of the technology (soft concerns). In the next chapter, I will investigate if (and how) the DIY-CRISPR kit, like bioart, can enhance the existing ethical debates on CRISPR by stimulating imagination.

IMAGINATION AND THE DIY-CRISPR KIT

1. INTRODUCTION

Ethical discussions on CRISPR-Cas9 genome editing technology, as elaborated in Chapter II, are more focused on 'hard impacts', relating to the consequences of genome editing on the values of health, safety and environment, than on the qualitative, subjective and value laden 'soft impacts.' This ignorance of soft concerns in public discussions regarding the desirability of CRISPR technology, it was argued, makes the quality of ethical debate poor and short-sighted. Based on Swierstra's (2015) claims, the anticipation of soft impacts, although a difficult task, was established to be an imaginative process which involves building scenarios. These scenarios are developed based on the investigation of how action and perception is mediated by the emerging technology. Furthermore, in Chapter III, it was observed that the ethical concerns raised due to the hands-on approach promoted by DIYbio activities and, due to the affects mobilized by bioart are related to the soft impacts of the technology. Taking these arguments and findings as reasons for addressing the research question of **Can DIY-CRISPR kits enrich the ethical deliberation and evaluation of CRISPR-Cas9 technology by stimulating imagination? If so, how**? in this chapter I will evaluate the imaginative potential[20] of the kit by referring to the theory of moral imagination, as discussed in moral philosophy.

In the upcoming section (Section 2), hence, I will review the discussions in moral philosophy regarding the role of imagination in moral deliberation based on the works of philosophers Martha Nussbaum, Mark Johnson, Steven Fesmire (on John Dewey's theory of Moral Imagination) and Mark Coeckelbergh. Following this, in Section 3, the role of the DIY-CRISPR kit in stimulating imagination about soft impacts of CRISPR will be analyzed using an evaluative criterion that I developed based on the insights from the theories on imaginative moral reasoning. The ODIN product website page, media articles and videos showing the use of the kit, user experiences (from interviewees and blog reports) and expert opinions will be used as resources for the evaluation. In Section 4, discussion of the results of analysis will be made along with some

[20] By imaginative potential, I mean the ability of the kit to stimulate moral imagination.

suggestions for users and organizers of the public discussions on CRISPR to improve the ethical debate on CRISPR using the kit. Thereafter, I will summarize my main findings in the concluding section (Section 5).

2. IMAGINATION AND MORAL REASONING

Imagination, as Liao & Gendler (2018) describe, is integral to a wide variety of human activities, and has been explored from different philosophical perspectives. 'Imagination', construed by Dewey, as the "capacity to concretely perceive what is before us in light of what could be" (Fesmire, 2003, p.65) can be considered as the basic definition for the term, within the context of this section, that will be expanded further based on its role in moral reasoning. Aristotle, as Nussbaum (1992, p.77) explains, does not have a single concept for imagination but what he means by *phantasia,* "the capability of human and animals to focus on concrete particular, whether present or absent, in such a way as to see it as something, picking out its salient features, discerning its content," is closely associated with the imagination as referred to in moral philosophy.

In this section, I will first trace the roots of the theory of imaginative moral reasoning. Then, I will discuss Johnson's theory of moral reasoning as an imaginative activity by elaborating on the imaginative structure(metaphors) he regards as crucial to moral understanding, and by defining the two functions of moral imagination outlined by him. Following this, I review the concept of moral deliberation as "dramatic rehearsal" which was proposed by Dewey and analyzed by Fesmire. Using the example of a hypothetical scenario concerning an emerging technology, I then illustrate how the different theorized roles of moral imagination might play out during a moral deliberation. Thereafter, I discuss Nussbaum's argument regarding the role of novels in cultivating empathy.

In the history of philosophy, many thinkers have resisted the claim about the value of imagination in moral reasoning.[21] Many of them subscribed to the Kantian conception of imagination as essential to aesthetic judgement but "too self-indulgent" for moral reasoning, due to its potential to "usurp Reason yielding victory to Feeling"(Fesmire, 2003, p.61). Pragmatists from Dewey to Rorty, according to Coeckelbergh (2007), developed an alternative view on how we reason about moral problems based on imagination, and drawing inspiration from their works

[21] I use the terms moral reasoning, moral deliberation and moral judgement interchangeably and synonymously throughout the chapter. Essentially, they refer to having to make a decision/rational choice and to act accordingly in the event of a moral dilemma.

(especially Dewey's), contemporary pragmatists such as Mark Johnson and Fesmire, and Martha Nussbaum, from the moral sentiment theory tradition, have further expanded on the concept of 'moral imagination.'[22] Johnson (1993, p.7) in his book *Moral Imagination* argues against the view of moral reasoning as "getting the correct description of a situation, determining which moral law pertains to it, and figuring out what action that moral law requires for the given situation." While, Fesmire (2003, p.3) in his urging for a Copernican revolution in ethics, i.e. shift in center of ethics from foundational principles to imagination, argues against contemporary moral philosophies like Kantianism and Utilitarianism that are focused on the "pursuit of a bedrock principle." Both Fesmire, referring to Dewey's writing on habit and deliberations, and Johnson, based on findings regarding human conceptualization and reasoning from cognitive science, claim moral reasoning to be an imaginative activity. However, Coeckelbergh (2007) nuances this claim by showing that both imagination and principles play an equal, necessary and cooperative role in moral reasoning[23]. Hence, moral reasoning as he argues can have different degrees of imagination.

Johnson (1993) based on theories from cognitive science, such as the theory of prototypes[24], frame semantics[25], metaphorical mapping[26] and narrative[27], question the underlying assumptions of the rule-governed tradition of morality. Moral reasoning, according to him, is a constructive imaginative activity because "it uses imaginatively structured concepts and requires imagination to discern what is morally relevant in situations, to understand empathetically how

[22] "Moral imagination" as referred to by these authors, except Coeckelbergh, is simply, the imagination that is involved in moral deliberation. In my use of term in this section, I do not take into concern the morality of imagination. I use moral imagination rather than the "use of imagination in moral reasoning," as Coeckelberg argues (see section 2.1), as its shorter and easier.

[23] Within the context of this thesis, I will not be assuming a position in the debate concerning if moral reasoning is only imaginative or both imagination and principle based.

[24] According to Johnson (1993), psychologists, linguists and anthropologists discovered that people tend to define categories such as bird based on the prototypical members of the category(robin) and the non-prototypical members(penguin) which differ from the prototypes. With relevance to moral theory, it has been found that moral concepts like duty, law & will, have prototype structure. Moral laws typically are based on such prototypical concepts and categories.

[25] Cognitive linguists have discovered that the terms and concepts we use derive their meaning from the frames or schemas that we develop to understand the specific situation. Hence, there are different moral consequences depending on how we frame the situation.

[26] According to this theory developed by linguists and psychologists, our understanding of concepts such as reason, knowledge, etc, are based on metaphoric mappings from the concrete domains of experience like movement, bodily experience of vision, etc.

[27] 'Narrative' as defined in this context is different from its definition as linguistic stories that are verbally shared or written as texts. Narrative as used here by Johnson is another imaginative mechanism, like metaphors and semantic frames, which recognizes the temporality of our experience and lives. Narrative, as a structure of our experience, according to Johnson (1993) provides the "broadest and most relevant descriptions of the meaning of an action."

others experience things, and to envision the full range of possibilities open to us in a particular case." He argues that structures of imagination such as images, image schemas, metaphors and narratives, thus, form our moral understanding.

Metaphors, which are central to Johnson's work, are considered as the chief imaginative aspect of moral understanding. He argues that moral reasoning is based on metaphoric concepts at two levels: "i) our fundamental moral concepts (e.g. will, freedom, law, duty) are defined metaphorically, typically by metaphoric mappings for a single concept, ii) the way we conceptualize a particular situation will depend on the use of systematic conceptual metaphors that make up common understanding of members of the culture" (p.2). Metaphors, hence, enters our moral deliberation by i) giving rise to different conceptualizations of a situation, ii) providing different ways for understanding the nature of morality as such (including metaphorical definitions of central concepts of morality like will, reason, good) and iii) acting as the basis for analogizing and moving beyond prototypical cases (or 'clear') to novel cases (Johnson, 1993). Johnson countered the claim regarding the prevalence of imagination in moral judgement undermining moral critique, by attesting that metaphors provide "alternate viewpoints and concepts from which to evaluate the merits of a particular moral position" (p.2). Furthermore, he emphasizes that metaphoric reasoning allows for learning from an experience by drawing out the metaphorical structure of previous situation (prototypical and unproblematic) to apply to the present situation (non-prototypical, novel and problematic).

Following his argument of how moral reasoning is imaginative as it depends on imaginative structures like metaphors, Johnson (1993) outlines the two functions performed by moral imagination as: i) envisionment of possibilities for acting and ii) empathetic projection into the experience of other people. The first function, as Johnson (1993, p.202) claims, is the "ability to imaginatively discern various possibilities for acting within a given situation and to envision the potential help and harm that are likely to result from a given action". According to Johnson (1993), in envisioning possible actions that would solve a problem which raises questions like "what I am to do?" and "how am I to treat others?" we try out "various possible continuations of our narrative" in a narrative-like format. In other words, our exploration of actions and their consequences in imagination takes the form of a narrative.[28] He, further argues that, narratives[29] enables us not only

[28] Narrative here refers to story telling.
[29] Narrative used in this line refers to its usage by Johnson as an imaginative structure like metaphors.

to explore consequences of decisions and commitments over an extended period of time, but also to reflect on the particularities that make up the fine texture of our actual moral experience (p.197). Moral imagination is required to envision possibilities for "fruitful, meaningful and constructive action" (p.203). Thus, for Johnson (1993) and Coeckelbergh (2007), who refers to this function as "projection of future scenarios", imagining possibilities for acting is same as exploring the consequences of action. These two roles of imagination, though consecutive and closely related, in my opinion needs to be distinguished. Dewey's metaphorical comparison of moral deliberation to dramatic rehearsal, discussed further, makes this distinction.

According to Fesmire (2003), Dewey's framing of moral deliberation as dramatic rehearsal, based on his study of the psychology of moral reasoning, clearly demonstrates how on encountering a problem, "alternatives suggest themselves and are tested in thought as we *imaginatively* envision them carried out" (p.35, emphasis in original). This imaginative trial of scenarios continues until a solution that appears to harmonize pressing interests, needs, and other factors of the situation is discovered. Fesmire, following Dewey, argues that "[t]hinking is provoked by a hitch in the workings of a habit" (p.35). Thus, as Johnson, based on Dewey's theory of "need-search-satisfaction"[30], in his recent lecture, explained that a moral problem which calls for a moral deliberation arises when one's habits get into conflict (Center for Values in Medicine, Science, and Technology, 2018).

The following excerpt from Dewey's *Human Nature and Conduct,* as cited by Fesmire (2003, p.69), explains the concept of dramatic rehearsal,

> Deliberation is a dramatic rehearsal (in imagination) of various competing possible lines of action. . . . [It] is an experiment in finding out what the various lines of possible action are really like. . . . Thought runs ahead and foresees outcomes, and thereby avoids having to await the instruction of actual failure and disaster. An act overtly tried out is irrevocable, its consequences cannot be blotted out. An act tried out in imagination is not final or fatal. It is retrievable.

Dramatic rehearsal, Fesmire argues, is the "reflective phase of the process of reconstructing frustrated habits" (p.78). Imaginative rehearsal is 'dramatic' because the alternatives that present

[30] According to this theory by Dewey, as explained by Johnson, our interactions with our environment mostly generate habits which incorporate aspects of our environment and so, most of our interactions are automatic and intuitive. However, when something disturbs our moral routine formed by habits, there arises a *need* to get it back to the normalcy. Hence, we *search* for methods and experiment with these methods until *satisfaction* is achieved.

before us are "intelligible only within the context of larger life narratives" (p.78). In other words, just as the "acts" within a drama make no sense outside the context of drama, moral behaviors are sensible only in the setting of a life-narrative, which in turn interplays with other life narratives. Thus, deliberation is equivalent to co-authoring a dramatic story with environing conditions in community with others. This claim supports Fesmire's understanding of deliberation as social. By highlighting that metaphors which define our basic moral concepts are held in common by all of us within a culture and that empathetic imagination allows us to inhabit the shared world, Johnson (1993) too argues in confirmation of the public, social and shared dimension of moral imagination.

The problem with the metaphor of dramatic rehearsal, as Fesmire (2003, p.80) indicates is that it can mislead the readers into thinking that moral deliberation is like a "dress rehearsal for a ready-made play" similar to the assumption behind rule-governed theories of morality. In Dewey's moral drama setting, the drama is experimental and unscripted with the "scenes are *co-authored* with others and with a precarious environment" and acting improvised (p.80, emphasis in original). To rectify this possible confusion, Fesmire (2003) compares moral reasoning with jazz improvisation. As in a jazz combo, improvisation in moral deliberation is an interpersonal activity wherein one must cleverly respond to each other with the aim of harmonizing interests. Moreover, the jazz player, according to Fesmire (2003, p.94), "draw[s] on the resources of tradition, memory and long exercise, and plays *into* the past tone to discover the possibilities for future tones in the way moral imagination enables us to see the old in terms of the possible."

To achieve this kind of coordinated impromptu thinking within a group, empathy is required. Empathy (or "fellow-feeling"), as Johnson (1993, p.199) defines, is "the ability to imagine *ourselves* in different situations and conditions at past and future times." According to Johnson, the role of imagination as empathetic projection into the experience of other people allows us to become morally sensitive as it "enlarges our own perspective through an imaginative encounter of the experiences of the others" and allows for "our own values and ideals be called into question from various points of view" (p.199). Dewey, defines empathetic projection as "entering by imagination into situation of others" (as cited in Fesmire, 2003, p.66). Empathy, according to Dewey (as noted by Fesmire) and Coeckelbergh, is necessary for moral reasoning but not sufficient.

The roles of imagination in moral reasoning as described so far are of relevance in the context of ethics of emerging technologies which often raises new challenges and moral problems.

Johnson (1993) argues that with development of new technologies, novel situations are created which are different from the historical prototypical cases and which require a re-definition of our moral concepts, based on the prototypical cases, for understanding. These novel cases presented by emerging technologies can be recognized as frustrating our existing moral routines and habits and thereby, posing a moral problem that calls for moral deliberation. Take for instance, the emerging technology of lab-grown meat which is claimed to eliminate the problems with the current meat industry by being sustainable, clean and ethical. Suppose that you are the supply manager of a supermarket chain who needs to decide between offering either lab grown meat or ordinary meat in the stores. As Dewey would describe, this new situation that disturbs your normal habit/routine calls for *reflexive thinking or deliberation*. In this deliberation, you *envision different ways of acting* in this situation, even imagining alternate actions besides just choosing either one of the options. In the envisionment of the possibilities, you also *rehearse* imaginatively what might be the *consequences of a selected action* and *who might be affected by this action*, such as what would happen to farmers who have cattle reared for meat production. By empathetic projection you will also imagine *how others will respond to your decision* such as how choosing the lab-grown meat would affect your company's acceptance amongst customers. While imaginatively deliberating how to act you might consider choosing the meat from local cattle breeders because you *empathize* with them and also your consumers who prefer non-lab grown meat; or you might prefer opting for the startup that offers in vitro meat because you *empathize* with the suffering animals and the future generation that might benefit from the reduced pressure on the environment due to cattle farming. Moreover, as a consumer of meat, your imagination may also be framed based on cultural *metaphors* such as "meat as natural" that should be derived from animals and not synthesized in a lab artificially. The *narrative setting* (metaphorical, historical and cultural framing of the situation) of lab-grown meat technology might also affect your decision making. This moral deliberation is *social* as you will rely also on external opinions and discussions (or "social intelligence" as referred to by Fesmire (2003)) on the topic. According Johnson(1993) and Fesmire (2003) even though this imaginative reasoning does not instruct you about the "right thing to do," it helps you to arrive at a decision by taking into account the different aspects of a complex situation instead of simply trying to find a fitting moral law that applies to the case.

Cultivating moral imagination, as Johnson (1993) stresses, is necessary to improve the quality of our moral understanding and reasoning.[31] The ability of moral agents using imagination to respond empathetically to each other, to envision the possibilities for action and also others' response to their action, is learned through experience and practice (Fesmire, 2003). According to Nussbaum (1992), literature such as novels, biographies and histories, are helpful in cultivating empathy. In the following snippet from *Love's Knowledge*, Nussbaum (1992, p.95) explains the essential role of novels in ethical inquiry:

> For novels, as a genre, directs us to attend to the concrete; they display before us a wealth of richly realized detail, presented as relevant for choice. And yet they speak to us; they ask us to imagine possible relations between our situations and those of the protagonists, to identify with the characters and/or situation, thereby perceiving those similarities and differences.

Johnson (1993, p.196), by referring to Richard Rorty and Nussbaum, argues that we learn from narratives such as literary texts about moral action because "our lives ultimately have a narrative structure." Furthermore, Johnson (1993) also endorses novelist John Gardner's claim that fiction is a laboratory in which the likely consequences of people's character and choices can be explored imaginatively.

Thus, to summarize the roles of imagination as described in pragmatist literature, following list provided by Coeckelbergh (2007, p.13) in his work *Imagination and Principles*, can be used:

> projection of future scenarios, the use of imagination to put yourself in someone else's shoes, the projection of personal and common ideals of life, our use of moral metaphors when we reason, the artistic expression of moral indignation, improvisation and tuning to create an action option and to reach agreement, the projection of images of society, politics, and technology, the projection of a moral self-image or moral images of others, and the role of images and metaphor in moral theory.

Of these enumerated roles, Coeckelbergh (2007) argues that the two important moral roles of imagination are imagining the consequences of one's actions and imagining being someone else (referred to as empathetic imagination commonly). All of the other described roles essentially

[31] This argument by Johnson implicitly affirms the conception that moral imagination might play only a limited (or no) role in moral reasoning. By arguing to cultivate imagination, he is stressing the need to increase the moral degree of imagination in reasoning.

perform one of these two roles. According to Coeckelbergh (2007) imagination, thus, allows moral movement: to the other and to the future.

2.1 Constraints to Imaginative Moral Reasoning

From the discussion made above on the theories which propose moral reasoning to be an imaginative activity, it might appear that moral imagination is sufficient for making decisions in a morally dilemmatic situation. However, Coeckelbergh (2007) in his work emphasizes the limits to the role of imagination in moral reasoning to support his thesis of principles, also having an equal and necessary role in moral deliberation. He identifies three types of constraints on imaginative reasoning, as theorized by the pragmatists: social, moral and epistemological. These constraints will be explained in the following paragraphs.

Accounts of moral imagination, as Coeckelbergh (2007) notes, are often challenged based on conception of imagination as free, subjective and its use implying extreme relativism in moral theory. These objections have however been addressed by Johnson (1993) and Fesmire(2003). According to Johnson (1993), metaphors act as constraints on reasoning to prevent subjectivism, because "there are shared bases for metaphors within and across cultures," and avoid relativism as "metaphors appear to be grounded in universal bodily experiences." Fesmire (2003), on other hand, argues the existence of socio-cultural limits on reasoning, as in the case of the jazz player who needs to rely on his memory and tradition while taking into consideration his fellow musicians in the setting of the deliberation, to avoid subjectivism. According to Fesmire, since morality is based on facts of social and personal life, claims about relativism can be dismissed (Coeckelbergh, 2007). Coeckelbergh, hence, in agreement with these arguments, emphasizes these social constraints to moral imagination.

Coeckelbergh argues that accounts of moral imagination are vulnerable to some form of conventionalism rather than relativism. He questions "[I]f moral metaphors and indeed moral reasoning in general is shaped by the culture we live in …to what extent can we stand apart from the cultural horizon" and "what if the tradition [in which we are embedded] itself is the problem" (p.30). For instance, if you live in a culture that regards stealing as a normal practice and if you decide to rob a bank after moral deliberation, does that justify the act as moral? Coeckelbergh, thus calls for moral constraint, in the form of a criterion, that can be used to judge the options which we envision and their implications as morally better or worse. Moral principles or rules, according to Coeckelbergh, can serve as moral constraints to imaginative reasoning. He also argues for

dropping the use of the term 'moral imagination' as it gives the false intuition that imagination is by itself moral. Coeckelbergh argues that imagination is morally neutral and it is the 'use of imagination' in moral reasoning, which is often followed by action, that can be framed as moral or immoral.

Epistemological constraints, as Coeckelbergh discusses, concern the limits on the capacity of imagination which are not necessarily barriers to imaginative reasoning. Firstly, the limits on our capacity to imagine, according to Coeckelbergh, prevent us from imagining "all possible scenarios, events, actions of people in a given situation." Reasons for this could be that we are not very imaginative, or our imagination is not sufficiently developed. Secondly, he argues that our imagination might be limited when we try to imagine being someone else (can we really imagine how it is to be tortured in a particular manner?). Imagination, Coeckelbergh argues, is dependent on the "certainty and amount of our existing knowledge, and on the quality and quantity of information we can gather." Novels, films, television and video games deliver knowledge that can be used by imagination which further aid moral development and decision making (Coeckelbergh, 2007).

3. IMAGINATION, THE DIY-CRISPR KIT & CRISPR

Based on the theoretical discussion made in the previous section, the importance and relevance of imagination in moral reasoning can be inferred. In this section, in addition to describing the benefit of moral imagination in ethical deliberations of emerging technologies, I will develop an evaluative criterion to judge the imaginative potential of an activity/object based on the concepts described in the theories of moral imagination. The criterion or set of questions, indirectly, enquires if the activity/object stimulates i) projection of possibilities for acting in a situation and the consequences of imagined action(s) and ii) empathetic projection i.e. imaginatively positioning yourself in someone else's place/situation.

Moral imagination is of value in the ethical deliberations concerning emerging technologies. Stimulating moral imagination in technology assessment related discussions can be argued to be beneficial as it would help in enriching and broadening the debate beyond questions such as should we permit or forbid a technology. Moral imagination brings to fore in such ethical discussions the different possibilities for acting, the probable repercussions of the actions and the different actors that may or may not be affected by the action and their response. Moral imagination achieves this by asking the deliberator(s) i) to be perceptive of situation and the narrative around

it, ii) to question the metaphors that make up their moral concepts and iii) to be responsive and empathetic towards those (un)affected.[32] Thus, to evaluate if a particular activity/object helps in improving ethical discussions by stimulating imagination, responses to the following questions needs to be considered:

- Does the activity/object under study, in its use or by itself, invite reflection about possibilities for action and the consequences of the actions?
- Does the activity/object under study, in its use or by itself, invite empathetic projection into the experience of others?

These two crucial questions, however, presupposes that the activity/object (or its use) poses a moral problem which requires imaginative moral deliberation. An enquiry into if and how the object creates a novel situation that needs to be solved through deliberation helps in understanding the relevance of activity/object in ethical discussions. Responses to these two seemingly abstract questions that have been posed in relation to the roles of imagination, can be made by relying on two imaginative structures discussed by Johnson (1993): metaphors and narratives. Imaginative projections, as Johnson argues, are influenced by the metaphors that frame an individuals' basic concepts and metaphors used to conceptualize situations (such as how the novel morally problematic situation is framed). Narratives-like structure, according Johnson and Nussbaum, helps with empathetic projection. The following list of guide questions, hence, aid in examining the role of the object/technology in the ethical discussions:

- What are the conceptual frames[33] used to describe the activity/object and (or) its use?
- What are the contexts in which activity/object is used and how are they framed? Or rather, What is the nature of the narrative in which the activity/object is embedded?
- Does the activity/object have a story-like structure?

In the following section I will be using these questions to evaluate the role of the DIY-CRISPR kit in enriching the discussions about CRISPR technology through stimulating imagination.

[32] Characterizing good artists as perceptive, creative, expressive, responsive of audience and skilled, Fesmire (2003) argues that a person involved in moral conduct (call "moral artist") must employ similar traits during moral deliberation. These characteristics are derived based on the comparison of moral conduct with art ("morality as art").
[33] By identifying how the activity/ object is conceptually framed in different ways, I trace the metaphors and metaphorical comparisons that influence the moral deliberation.

3.1 Role of DIY-CRISPR kit in ethical discussions of CRISPR

3.1.1 The Criterion of evaluation

The ODIN's DIY-CRISPR bacterial transformation kit has been widely used by biology enthusiasts at homes and in community labs. Several DIYbio labs and networks such as the Waag's Open Wetlab, Hacketeria and groups such as the Bioart Society have used the DIY-CRISPR kit as part of their workshops. In this thesis, the main enquiry of research is regarding the potential of the DIY-CRISPR kit and its use in triggering imagination, that would enrich the morally dilemmatic debates about the desirability of CRISPR-Cas9 technology. According to Swierstra (2015a), imagination is needed to improve ethical debates as it allows building scenarios for anticipating the soft impacts of new technologies. However, Swierstra, does not define the type or process by which the imagination, that he argues for, stimulates anticipation of soft impacts. Whereas moral imagination, as argued prior, can enrich ethical deliberations through its roles of projecting future scenarios about actions and consequences of actions, and empathetic projection. Based on the assumption that imagination relevant to raising soft impacts is a subset of moral imagination, I will evaluate if the DIY-CRISPR kit has the potential to invoke moral imagination. In this general enquiry about the imaginative potential of the kit, I will be attentive to instances (if any) in which projections regarding the future and alternate applications of CRISPR, and the consequences of such applications on our values and society (soft impacts) are made.

Based on the relation between imagination and ethical deliberation described above, I will be using the following set of questions as the criterion to evaluate if the kit and/or its use i) poses a moral problem, ii) invites thinking about possibilities for action and their consequences with relevance to CRISPR and iii) invites developing empathy towards others who might be affected by the action[34] :

a. What are the conceptual frames used to describe the DIY-CRISPR kit and its use?
b. What are the contexts in which DIY-CRISPR kit is used and how are they framed? Or rather, what is the nature of the narrative in which the DIY-CRISPR kit is embedded?
c. Does the DIY-CRISPR kit have a story-like structure?

[34] i) is the condition for moral imagination and ii) & iii) are the roles of moral imagination.

Responses to a) and b) are of significance in discerning how the kit and its framing affect the projection of possibilities for action and their consequences and posing a moral problem (i.e. i) & ii)), while answer to c) is of importance to understand empathetic potential of the kit.[35] This separation of responses is however not strict, as some inputs regarding the conceptual and contextual framing of the kit might be valuable to analyze its role in empathetic imagination. I will rely on the discussions about the kit in articles, videos and blog entries about using the kit, the ODIN website page and expert and user experience[36] interviews that were conducted as resources for my evaluation in the next section. In addition, I also considered the direct replies of the experts and users to the question regarding the imaginative potential of the kit as supplementary to my findings based on the criteria mentioned above[37].

3.1.2 Evaluation

Before going into the evaluation of the kit using the criterion, it needs to be investigated if the pre-condition for moral imagination, which is of posing a moral problem by frustrating the habits and presenting a novel and non-prototypical case, is fulfilled by the DIY-CRISPR kit or its use.

Hence, the question ***Does the DIY-CRISPR kit or its use frustrate one's habit or present a novel case?***

Overtly, the kit, in and of by itself, based on its design and components do not seem pose a moral problem. While its availability and use appear to have raise biosafety and biosecurity concerns in the larger context of debates and worries about allowing unregulated amateur biologists to experiment with a controversial technology like CRISPR in homes and community labs that might lead to the creation of pathogenic organisms and their release. These concerns raised, usually from outside the DIYbio movement, can be recognized as indicative of some individuals' perception of the kit as a novel case that breaks usual habit. However, to those within the DIYbio movement, who have actively used kits and conducted experiments regularly, this kit may not be something non-prototypical or unusual.

Researcher and scholar, Kuiken (2016), however, drew attention to the uniquely worrying aspect of Zayner's initiative. According to Kuiken, unlike other kits within DIYbio movement,

[35] This is based on Nussbaum argument that novels cultivate empathy. So, by enquiring about story-like structure, I am concerned about format of the texts and descriptions attached to the kit.

[36] All of the experts that were interviewed used the kit in a collective setting, as part of a workshop, either as a participant or workshop guide. While, 2 of the users experimented with the kit in their homes and 1 of them used it during a workshop that he led.

[37] Refer Appendices A & B.

Zayner's campaign failed to comply with DIYbio.org code of conduct, especially the biosafety protocols. The kit may be considered as presenting a novel case, based on this safety related concerns posed by Kuiken. By disregarding biosafety rules, evident from the video attached to the campaign where petri dishes were shown to be stored next to food in a refrigerator, some DIYbiologists argue that Zayner is setting a bad example for his audience (Yin, 2016). Zayner's other stunts such as injecting himself with myostatin knockout gene, has spurred ethical discussions about self-experimentation.

The discussions on the DIY-CRISPR kit, subdued for a while after it was released for purchase, mainly due to the reason (I speculate) that experts became aware of limited scope of use enabled by the kit. Experts and users that I interviewed were of the similar opinion that the kit is very basic and permits only the specific application. However, the recent finding by German Authorities that the bacteria were pathogenic in few of kits which were tested, called for discussions on the safety of trade commodities and also the prohibition to use the kit within Germany (Chardonnet, 2017). Within the context of regulations imposed on the kit and on genome modification, as in the Netherlands, I would claim that the DIY-CRISPR kit and its use raises a moral problem wherein the DIYer must decide if he/she wishes go against the regulation by purchasing kit and even if he/she purchased it, should they conduct the genome editing procedure which is illegal without proper licenses.[38] Hence, depending on the regulatory policies of adopted by different countries and the awareness amongst the citizens about such regulations, the kit may or may not pose a moral problem.

Thus, having addressed the pre-condition for moral imagination, I move on to the evaluation of the DIY-CRISPR kit based on the criterion developed in previous section and the direct responses of the users.

a. What are the conceptual frames used to describe the DIY-CRISPR kit and its use?

I relied on phrasings and descriptions made in in context of the kit and its use to identify the conceptual frames adopted. These framings affect people's conception about the kit and its use. Since Zayner's campaign on Indiegogo platform, the kit has been associated with the idea of "learning". More specifically the kit was advertised under title of the campaign "Learn Modern Science By Doing" (Zayner, 2015). In the product description of the kit states that the kit contains an "example experiment" which "*teaches* you many molecular biology and gene engineering

[38] This was one of the main questions in Waag's Biohack Academy.

techniques"("DIY Bacterial Gene Engineering CRISPR Kit," n.d.). The use of the terms "experiment" and "protocols" in relation to the kit can be viewed as trying to indicate the scientificness of the kit. These descriptions hence metaphorically compare the kit to a "learning/pedagogical scientific tool."

In opposition to the claim that the DIY-CRISPR is only a pedagogical tool like any other kit within DIYbio, Pieter van Boheemen argued that the kit is very ideologically motivated (personal communication, June 21,2018). According to him, the language used, and activities performed by Zayner in relation to the kit is indicative of his technoliberalist and anarchist attitude. The kit, which Zayner (2015) claims can be used by everyone irrespective of their knowledge and experience in biotechnology, thus, can be compared to as the symbol of "freedom" from the restrictions of science by allowing easy and affordable access to CRISPR.

Words such as "easy to use" and "simple" have also been associated with the DIY-CRISPR kit. Though unclear if these associations come from the DIYbio literature which often describes their activities as less complex and easy, or from the CRISPR literature which reports the technology as easy, the comparison of the kit as "easy and simple" has influenced how the public perceive CRISPR technology. Moreover, the metaphorical comparison of CRISPR technique to the "search and replace function in the word processor" along with the terms and images used to explain the technology such as "edit", "cut" and "scissors splicing the DNA" reinforces this framing of the experiment within the kit as uncomplicated. Since the kit simplifies the whole complex process of CRISPR genome editing and is advertised as requiring just approximately 10 hours of work over the course of 2 days (a weekend), the users, I infer from the interviews and videos on how the kit is used, regard the kit as "entertainment", "fun", "hobby" and as a "playful toy." For instance, one of the users who used the kit with his children, stressed that he bought the kit because it was a "modern equivalent of [his] childhood chemistry set."[39] Kuiken argues that people miss the level of sophistication associated with the CRISPR-Cas9 technology because of this way of framing promoted by the kit (Paul, 2015). Moreover, the whole technological experiment framed as "DIY" and "kit", I speculate, also makes the users consider the technology with less seriousness and the assembly of materials to perform the experiment as a "hobbyist's toolkit."

[39] Chemistry sets which were manufactured in early 20th century for children as toys.

Another conceptual framing of the kit comes from genetic engineering and CRISPR literature, i.e the metaphorical comparison of CRISPR technique as "playing god" with genomes of species. Derived from this analogy, one of the writers, Tarantola (2016) titled his text on the experience of using the kit as "I played God with The Odin's DIY CRISPR Kit" while Sneed (2017) remarked regarding the use of the kit as "But for all the godlike powers that I imagined CRISPR gave me, I actually had little say over what I did to my bacteria." Tarantola (2016) phrasing of his experience with the kit as "I was *recently afforded the opportunity* to create a new kind of bacterial life thanks to the DIY Bacterial CRISPR Kit …", can be identified as representative of his satisfaction in being given the power to create something (like a God). While Sneed's (2017) observation that "everything was predetermined" and that she made zero decisions during the experiment shows the disappointment in realizing the fallacy of the conceptual framing of the kit as allowing to "play god".

b. What are the contexts in which DIY-CRISPR kit is used and how are they framed? Or rather, what is the nature of the narrative in which the DIY-CRISPR kit is embedded?

The DIY-CRISPR kit, as I mentioned before, has been used by biologists, enthusiasts, amateurs and experts in two different contexts, namely, in the private setting of their homes or 'garage labs' and in collective settings of DIYbio community labs and workshops. In the private settings, the above-mentioned metaphors and descriptions like "learning tool", "entertainment," "fun" and "hobby" frames the context of use of the kit. For instance, in a Youtube channel called "Epic Danny," Danny, a boy of age between 8-12, with his parent shows them using kit, from unboxing the kit to performing the final step of transforming the bacteria, in a series of videos (Danny, 2016). From these videos it appears that both Danny and his parent learn to use the different instruments that came with the kit while following the different instructions in a careful manner and having fun during the process. There seems to be an element of "excitement" and "curiousness" too in the use of kit by amateurs. For instance, Naomi Brockwell, who is a tv producer and has a channel which discusses technological issues, seems to have used the kit to participate in the "trendy" topic in technological debates and out of "curiosity" about what the kit does. The kit as one of the users commented, was purchased and used with the intention of learning about the technology and figuring out if the CRISPR technique would help with his idea of "grow fungi, bacterium, algae, etc. to "fight back" against environmental destruction." Extending the use of the kit beyond its intended purpose, however, is done mostly by bioartists and DIYers who have experience in the

field of biology. As Nora Vaage confirmed, such advanced biohackers use the kit as a "starting kit which gives the basic tools to do CRISPR" (personal communication, June 11, 2018).

In the collective setting, DIY-CRISPR kit is often used as an initiator of discussions concerning the technology of CRISPR. The kit is used as a tool to understand the basics of CRISPR. Vaage in recollecting her experience of attending, the "merry CRISPR" event which was organized by Bioart Society, Finland in December 2017, described how the "context of the workshop was to use the ODIN kit with an artistic spin" (personal communication, June 11, 2018). She further elaborated that the workshop was followed by in-depth discussions and the creation of a Facebook group wherein people now share new developments and music that they discover with CRISPR themes. Vaage also commented that generally workshops and events organized under the DIYbio movement which make use of such kits have some discussions, that may happen while collectively performing the experiment or afterwards, wherein they reflect about "what can we do with this[technology] and what could be the societal implications of this and that use of CRISPR, what will be potential applications, what can more concretely be done with this and how can we use it because it is seen as useful tool." The context of such collective settings, according to Vaage and Roland van Dierendonck, can influence the participants' thinking (personal communication, June 11 & July 5, 2018). To illustrate, Vaage gave the example of the "Cheese & CRISPR workshop" that was organized as part of the Hacketeria.org network in Japan, which framed its aim of event as to "demystify the current hype around gene-editing technologies" by showing how cheese making has traditionally depended on CRISPR-like biotechnologies and to "speculate about how we can integrate them into public use, play, food and games for a better world." Vaage speculated that participants in such specifically contextualized workshops "would think of scenarios for the technology but maybe not as much in terms of different scenarios and what could be positive and negative implications of developing this[technology] in different organisms and so on." In other words, the scenarios developed will depend on how the workshop is structured and contextualized.

c. Does the DIY-CRISPR kit have a story-like structure associated with it?

Novels, biographies and histories with story-like structure as Martha Nussbaum argued have the potential to cultivate empathy. In the context of the kit and its use, empathetic projection that I am concerned with is the empathy towards the bacteria that undergoes transformation (who is affected now?) and the empathy towards others in the future who might be affected by the current decision

about CRISPR technology (soft impact related). The textual materials associated directly with the kit include the product description on the ODIN website and the protocol of experiment attached to the kit. The description on the website for kit, like discussed previously, conceptually and metaphorically frames the kit and does not have a story-like structure.

The protocol for conducting the experiment is the other textual material that can be analyzed for story-like structure. Most of the experts and users described the instructions for using the kit as "complex", "amateurish" and "erroneous." The kit's protocol has been compared to baking instructions (Tarantola, 2016) and recipe instructions in a cookbook (Sneed, 2017). Tarantola (2016), who used it soon after it was released, for instance, commented that the protocol is "fairly barebones" and "continually-evolving" with the ODIN team changing its content frequently for clarity. The step-by-step instruction, one of users, claim is very similar to the "computer scene[40] back in 80s [where] it was very much figure it out as you go along." This "figuring out by yourself… how each piece of this biological puzzle fits together rather than being spoon-fed information," according to Tarantola (2016) was an enjoyable mental challenge[41]. This textual narrative associated with the kit, from my personal experience of reading it, seems to explain which step to do next without providing much information on why the step is being conducted and how it affects the whole experiment. Thereby, the protocols do not provide adequate material to think about consequences of each step performed within the context of the kit (micro level) and also to project the consequences of genome editing using CRISPR on a macro level. Hence, it can be argued that the protocol, though can be an effective learning tool to some by acting as a mental challenge, does not provoke empathy towards the bacteria that is being modified and/or towards the others that might be affected in the future.

Effect of conceptual (metaphors) and contextual(narrative) frames on the imaginative potential of DIY-CRISPR kit

Having examined the different conceptual frames used to describe the DIY-CRISPR kit, the contexts in which it has been used and how the contexts are framed, it is important to determine how these factors affect the user's ability to imagine possibilities for action and their consequences, and to empathize with the other (in this case, the "other" can be the bacteria and/or actors in the future). In private settings, specifically, the metaphorical description of the kit as "experimental

[40] I interpret the user is referring to the computer hacking culture.
[41] This opinion was in relation to the older version of the protocol.

pedagogic/learning tool" and as "symbol of freedom from the restrictive boundaries of science," I would argue is a reason for the users buying the kit. While the framing of the kit as "easy-to-use", "simple" and "toy-like," I would speculate as having two contradictory effects on the imagination of the user. On the one hand, by referring to the kit in these manner, the user might not consider the CRISPR enabled genome modification as a serious and revolutionary technology, and thereby would ignore its actual complexity and potentiality. The users might be driven by the "fun" and "entertainment" aspect of it that they might fail to notice/pay attention to the technology and its impacts. In addition, the simplification of the genetic engineering methodology by the kit, hence, would only worsen this effect. On the other hand, alluding to the description of the kit as "simple, that everyone can do it" can trigger imagination regarding the consequences of the action (using the kit). Sneed (2017), for instance, questioned "what does "easy to use" mean?" and explains how she wondered, "Is CRISPR so easy that even amateurs like me can make meaningful contributions to science? And also, does this new technique make gene editing so accessible that we need to worry about DIY scientists cooking up pandemic viruses in their basements?" She also highlighted that her security concerns of people synthesizing pathogenic organisms deliberately were exacerbated with stories such as "What Happens If Someone Uses this DIY Gene Hacking Kit to Make Mutant Bacteria?" showing up when she googled for 'DIY-CRISPR.' Thus, the controversial narrative surrounding the kit relating to biosafety and biosecurity issues seems to have provoked a sort of reflective thinking about the consequences in addition to the metaphorical comparison of the kit as "simple" and "easy-to-use."

In the collective setting of workshops, the kit has been used as instrument for starting the discussions on CRISPR. However, the framing of the workshop, for instance as an event to explore CRISPR from a bioartistic perspective or as an event that aims to demystify CRISPR, influences how the participants project future scenarios. This, hence, orients the whole discussion in a particular direction. The contextual framing of the workshop and the kit, hence, might limit people's imagination to specific topics such as safety and security concerns, for example. Van Dierendonck, from his experience in guiding the use of DIY-CRISPR kit during the Biohack Academy, emphasized that the participants thinking is shaped by "how you introduce the kit, give context and build the setting and narratives" (personal communication, July 5, 2018). As mentioned earlier, discussions that occur within such workshop usually are beyond the standard questions of should we permit or forbid a technology. The debates are more focused on societal

and ethical implications of the technology. Thus, it can be argued that in such collective settings, which are appropriately contextualized, moral imagination may be stimulated on purpose and so, deliberations about future scenarios of actions, consequences and those (un)affected by the consequences can occur as opposed to in private settings such as homes, kitchens and garage labs where the kit might be used.

The descriptions of the DIY-CRISPR kit as "easy-to-use" and "toy-like," have some influence on the users' ability to develop empathy towards the bacteria that is genetically modified and towards future others. Our usual conception of bacteria as having no intrinsic value in comparison to other multicellular organisms like a frog or plant, compounded with our understanding of the kit as playful object, I speculate, does not evoke any kind of empathy towards the organism. Van Dierendonck, for example, mentioned the difficulty in projecting from what you see as effects on bacteria after genetically modifying it using CRISPR to the implication and application of the technology on humans (personal communication, July 5, 2018). Moreover, the frequent clarification by Zayner (in the FAQ section of the campaign page, in the protocol of the experiment and on the label of the packet containing the bacteria[42]) that the *E.coli* which is transformed as part of experiment is non-pathogenic and the modification does not yield anything harmful, might also serve as a reason for not being able to empathize with the bacteria.

Agnieszka Wolodzko described that during her use of the kit (in a workshop), she couldn't position it [the kit and the experiment] with anything that she knows (personal communication, June 14,2018). Performing the experiment by simply following the instructions that say "pipette fluid here and there," in her opinion, did not give any insights about the risks. To her, the overall kit inclusive of the protocol, invisible organisms and tools, did nothing except just give the feeling of being engaged in something risky[43] and something exciting. Wolodzko's questioning of "how do I change the organism that I don't even see" and unrelatability to the experiment seems to indicate the failure of the kit and its use to trigger empathetic imagination.

3.1.3 User experiences about the imaginative potential of the DIY-CRISPR

In the above section, I evaluated the capacity of the kit and its use to stimulate imagination by looking at imaginative structures such as metaphors and narratives. The direct response of the

[42] The label on the packet containing E.coli bacteria in the kit said "non- pathogenic." I observed this while watching the unboxing video by Danny(2016).
[43] She was informed about the risks of CRISPR genome editing.

experts to my query "Do you think the kit promotes imagination of say potential ways of using of the technology/implications of using the technology/the moral aspects of using it)? If so how?" and of users to the question "Did using the kit make you think about the possibilities and potential of the CRISPR-Cas9 technology? If so, how? Did you discuss these topics with others (if so, who and what was discussed)?" gave interesting insights that could be used to supplement the prior conducted evaluation of the kit.

The opinions of the experts on the matter was mixed. Two of them responded positively while the other two were not so convinced with idea that the kit could trigger imagination. The reasons for objections to the idea that the kit stimulates imagination, according to one expert, were the weak technical and design aspects of the kit. He commented that the kit does not make you think much because the instructions are unclear and complex, and the experiment is neither great nor educational. The other expert who also disagreed with the idea claimed that "with the kit you are trying to expand the borders of science but still there exists a border because you follow the rules which are complicated." In other words, the kit does not permit free thinking and reflection as other kitchen biology[44].

All the three users confirmed that the kit and its use made them think about the possibilities and potential of CRISPR. One of them responded by saying that the use of the kit got him "worried about malicious applications by bad actors, and the possibility of catastrophic mistake." Another user, for instance, expressed that after media articles with relevance to the panic surrounding the kit and CRISPR started showing up, he got concerned about his "new niche hobby." The kit, according to the third user, expanded his interest in the topic of CRISPR and allowed him to extend his understanding and learning of CRISPR to his project of modifying yeast to produce scents (like lavender). Being a person who modified mice using the old techniques during his research years, this user commented that understanding how CRISPR works and how it can be used in different ways (for the which the kit was responsible) made him think how CRISPR would have accelerated his genetics research back then.

Thus, from the experience based responses, it is evident that the use of the kit does have a potential to stimulate projection of future consequences (safety and security related), evaluation of

[44] The expert was in favor of kitchen biology wherein the materials used are easily available in supermarkets and at homes. The expert argued based on experience that experimenting in such a kitchen like setting with cheap and non-harmful ingredient, permits one to be creative and inventive as possible.

current situation and projection of moral self-image (based on the concern of new hobby), projection of new ways of acting (extending knowledge to a project) and retrospective projection (imagining the past situation in the light of the new situation).

4. OBSERVATIONS & DISCUSSION

From the evaluation that has been made in the previous section, following results can be inferred about the potential of the DIY-CRISPR kit and its use in raising a moral problem and stimulating imaginative moral reasoning about CRISPR:

i. The kit and its use, though overtly does not raise a moral problem, unless in a regulated environment, is embedded in the ethical discussions relating to the safety and security of DIYbio activities. These safety and security concerns which have been raised because some people view the kit as frustrating their habits and presenting a novel case[45].

ii. In private settings, the metaphorical framing and narrative of the kit as an "easy to use educational kit that is fun and simple" can either hinder the imagination of future scenarios about the CRISPR, as users fail to understand its complexity, or it can promote the projection of future consequences of allowing technology like CRISPR in the hands of non-scientists (safety & security concern).

iii. In collective settings, depending on the metaphors and narratives used to contextualize the environment, the kit can act as an initiator for discussions relating to CRISPR by calling for purposive moral imagination about possibilities for actions and their consequences, and those implicated by the action through empathetic projection.

iv. The metaphorical framing of the kit and its use along with the non-storylike structure of the protocol attached to the kit, does not evoke empathy towards the bacteria that is being modified or to those in future that might be affected by current action.

In addition to these results, users' experience and opinions indicate that the use of the kit can evoke imaginations about alternate ways of acting and future consequences, retrospective thinking, and images of moral self.

The use of DIY-CRISPR kit, as majority of the accounts on it show, has been considered to be a learning event. The kit's use may not have explained and taught CRISPR technology in its

[45] In general, my argument is that the kit does not pose a moral problem but is embedded in a context that makes it appear as frustrating habits and presenting a novel case. I draw on this conclusion based on the observation that many DIYers purchase and use the kit. If it presented a moral problem, overtly, this would not have been the case.

entirety, but it seemed to have increased the user's interest to explore more about the topic. As Tarantola (2016) described, the kit sure does teach some technical skills such as micro pipetting, making agar plates and streaking. An observation, that was not covered by the evaluation criterion and which I believe deserves attention, is that of the role of the experimental results. Succeeding/failing to achieve the results of the bacterial transformation (i.e new colonies on plate with streptomycin medium) seemed to have promoted the user's thinking about science and rigorousness of scientific practice. One of the users after saying it took him 5 tries to get the result added that the kit taught him how being careful is an important aspect. Tarantola (2016) commented that not getting the expected result, though was frustrating, made him realize that biohacking is hard and such failures are "half the fun of being a scientist[without a degree]." While for another user, who had prior experience with biotechnology, was surprised to get results on the first try as such situations are "rare in science." Some sort of conflict of between what was expected by the user and what actually happened in terms for the experimental results seemed to have provoked thinking about science. This reflection stimulated regarding the difficulties of "doing" science based on failing to achieve the result in this acclaimed "simplified" version of CRISPR may be helpful in evaluating the biosafety and biosecurity concerns (hard impacts) that are often raised in relation to the technology.

Based on my analysis of how people associate with the kit depending on its conceptual and contextual framing, I would argue in response to the research question that the DIY-CRISPR kit does trigger some imagination that is of relevance for the ethical discussions on CRISPR in both collective settings and private settings. In private settings, where individuals seem to use the kit on their own, the kit does not provoke much imagination about the possibilities for action and their consequences, and empathy towards the other, in comparison to when it is used in collective settings. What the evaluation results and expert opinions and user experiences showed is that the use of DIY-CRISPR kit, in an appropriately contextualized collecting setting like the DIYbio workshops, has the potential to (or can) stimulate moral imagination which in turn can improve the quality of the discussions.

However, it needs to be emphasized that the imagination that I argue as evoked by the kit, is moral imagination and not just imagination about soft impacts of technology, specifically. I had argued, prior to the evaluation, that the imagination about soft impacts can be considered as the product of one of roles of moral imagination. Stimulating moral imagination thereby might result

in reflections about both hard and soft impacts of the technology. The results of the evaluation of the moral imaginative potential of the DIY-CRISPR kit in private settings, indicates that the kit triggers imagination about(or relevant for anticipation of) hard impacts to a larger extent rather than of soft impacts. I make this argument because the kit and its use does not seem to have made the users reflect on soft impacts related questions about the implications of the introduction of the technology to our values, identities, lifestyle and relationships such as "would CRISPR enabled genome editing of future generation change our conception of 'care'? Would we regard children as manufactured goods?(Lander, 2015), How would curing genetic impairments such as blindness change the identity of the disabled in the society? If germline editing is the new norm, can parents be held responsible for not editing their child? Would CRISPRed food be regarded as "natural" by consumers? The limited amount of imagination that has been triggered seems to be about the hard impacts i.e about the biosafety and biosecurity concerns of using the kit and of CRISPR. In collective settings, on the other, I would argue that imagination about soft and hard impacts are evoked in the participants based on how the event, discussion and the technology are contextualized.

Based on the observations made of the poor quality of current ethical discourse on CRISPR in chapter II, I would like to claim that the imaginative potential (although limited) of the DIY-CRISPR kit can be of use in technology assessment(TA) related events. The kit can enrich deliberations in TA events, organized with the aim of assessing the moral desirability of CRISPR-Cas9 technique, which are currently lack imagination and "cerebral"[46]. The "hands-on" learning and imaginative thinking enabled by the kit's use can, thereby, improve the debate by raising both hard and soft concerns of CRISPR. In case of participatory TA(pTA) of CRISPR, where the general public is invited to participate by expressing their opinions and concerns regarding the technology, the kit can be value as it might trigger different responses and reflections amongst the participants with varied backgrounds.[47]

Besides recommending the use of the DIY-CRISPR kit in TA settings, I would like to suggest a change that can be made to the kit and its use for amplifying its potential in triggering

[46] By "cerebral", I mean that the discussions are based on hard facts and scientific data rather than on experience of doing something. Cerebral would be the antonym of practice/ praxis based.

[47] Different responses and reflections may be invoked as moral imagination dependent on one's memory and tradition. The type of imagination and reflection is also dependent on how the pTA is framed. Though rare, it might also happen the participants have very similar responses.

moral imagination. Based on its current design as well as framing the imaginative capacity of the kit is very limited and can be improved. Attaching a story (or stories) to the kit or contextualizing its use within the narrative of a story can be beneficial to the context of enriching ethical debate. Stories,firstly, Swierstra (2015a) argues are good vehicles for anticipating the softer impacts of technology. According to him, stories aid in imagining "how we respond to changes in our environment and invite us to evaluate newly evolving practices from the perspective of insiders." Moreover, stories are a good way to present possible futures (Swierstra, 2015a). Secondly, as Nussbaum (1992) argued, stories allow for developing empathy. Since, the DIY-CRISPR kit in its present form does not present a novel case or moral problem to the user[48] (that makes the user think "what should I do now?") and have the capacity to evoke empathy, I would argue that attaching it to a story (or stories) that outlines a moral problem, makes use of appropriate simple metaphors to trigger emotional response[49] and gives the user responsibility as the decision-maker in the context (for instance, by asking to position as the decision maker), will improve its imaginative potential. Such an addition might also stimulate imagination amongst DIYers and laymen using the kit in their homes.

Empathetic projection capability of the kit can be improved by making the use of the kit more relatable to the user as well as the experiment and its result more visible to the user. The capability of the ODIN's recent Frog Genetic Engineering kit to develop empathy in the user, I speculate, would be larger than with the Bacterial transformation kit as the organism under modification, to us, is not relatable (or no value) and the changes performed on it are not so visible. This limitation of the kit can be solved by using metaphors such as "bacteria as your pet" which can evoke relatability and emotion towards the bacteria within the story that may be attached to the kit. By suggesting this addition to the kit for improving its imaginative potential, I do not, however, claim that if these changes are implemented moral imagination will triggered in every user but that they could improve the chances of imaginative reasoning. The capacity to imagine can vary from individual to individual and may be limited, as Coeckelbergh (2007) described.

[48] See footnote 45.
[49] Based on the heuristics developed by Siebrand's(2007) in his master thesis to optimize and provoke Moral Imagination.

5. CONCLUSION

In this chapter I addressed the research question of "**Can DIY-CRISPR kits enrich the ethical deliberation and evaluation of CRISPR technology by stimulating imagination? If so how?**" based on theories in moral philosophy which state that moral reasoning is imaginative. This theory has its roots in the philosophical tradition of Pragmatism. By reviewing the works of contemporary philosophers Martha Nussabaum, Mark Johnson, Steven Fesmire, and Mark Coeckelbergh, the two important roles of moral imagination were delineated as i) projection of possibilities for acting in a situation and the consequences of imagined action(s) and ii) empathetic projection. The social, moral and epistemological constraints to the use of imagination in moral reasoning were also described. Following the description of the theory, I discussed how moral imagination is of value in the context of ethics of emerging technologies and developed a set of guiding questions to evaluate if the use of an object/technology stimulates moral imagination. I, then, used this criterion to evaluate the DIY-CRISPR kit.

The evaluative criterion analyzed the effect of the conceptual framing of the kit, its different contexts of use and contextual framing, and story-like structures associated with it on the imaginative potential of the kit. Based on the results of the evaluation and the user experiences and opinions regarding the imaginative potential of the kit, I inferred that the DIY-CRISPR kit and its use has a low potential to stimulate moral imagination that would enrich the quality of the ethical debates on CRISPR. I also identified that the imagination that is provoked, especially in private settings, are about the hard impacts of the technology rather than soft impacts. In collective settings, however, imagination about soft and/or hard impacts may be triggered based on how the setting is contextualized based on its purpose. Furthermore, I claim that the imaginative potential of the DIY-CRISPR kit may be of value in pTA and TA events on CRISPR.

To improve its potential for triggering imagination, I suggest attaching the kit with a story(ies) and contextualizing its use within a story that poses a moral problem and is carefully worded with metaphors in such a way that it allows for developing empathy towards the other. Complementing the kit's use with stories, I regard will be of benefit in both private and collective use, as it can evoke moral imagination about a particular application of CRISPR (like environmental engineering).

CONCLUSION

The main aim of this thesis, which began with introducing to the reader the panic that the initial campaign for ODIN's DIY-CRISPR kit produced, has been to discern the possibility of using the DIY-CRISPR kit in the context of assessment related discussions on CRISPR-Cas9 technique conducted as part of TA and pTA events. However, before determining the value of the kit in such workshops, I had to analyze the current discussions on CRISPR. In the second chapter, after providing an introduction to the functioning, applications and challenges of CRISPR, using the NEST ethics (consequences, distributive justice, deontology and good life arguments) developed by Swierstra (2015b), I reviewed the different types of ethical arguments posed in favor of and against the genome editing technology. This review of the current ethical debates on CRISPR showed that hard impacts, relating to harm done to values of safety, environment and health, are dominant while reference to soft impacts, related to the moral implications of the technological introduction to our values, identities, lifestyle and relationships, appeared to be negligible or almost absent. The deontological and good life arguments of "playing God" and "sanctity of gene", which can be identified as related to soft impacts, is not just specific to CRISPR technology rather to all genome editing technology. Swierstra & te Molder (2012) argue that deliberations that lack discussions about soft impacts are short sighted. Imagination, according to Swierstra (2015a), is necessary for building scenarios that allow for anticipating the soft impacts. Thus, based on the normative assumption that high quality ethical debates are imaginative and concerned about the soft impacts of the technology I claim the quality of current ethical debates on CRISPR as poor.

Since, the DIY-CRISPR kit is the product of DIYbio movement, I then looked into the different activities and discussions surrounding the movement, especially that of bioart. Bioart is considered to be an activity under the DIYbio movement where artists use living organisms as media and/or biotechnological methods for their art works. Vaage (2016) argues that bioartworks are "materialized visualizations of futures." The sociological research by Holmberg & Ideland (2016) on the role of bioart in ethical discussions on biotechnologies claimed that bioart and bioartistic practices are "imagination laboratories" that have the capacity to evoke ethical response by mobilizing affects based on the structural form of the art work. The ethical response that is stimulated questions the boundaries of human/non-human, living/dead, which are taken as fixed

in "rationalist" ethical deliberations about the cost-benefit analysis of a technology. Hence, bioart, based on authors Vaage(2017) and Holmberg & Ideland(2016) arguments, seem to trigger imaginations required for anticipating soft impacts.

Drawing on this finding that the imaginative potential of bioart allows for improving the ethical debate through raising soft concerns, I then moved to evaluate if the kit and its use has a potential to trigger moral imagination. Based on the insights from pragmatist tradition on the role of imagination in moral reasoning, I developed a set of questions, which I refer to as evaluation criterion, to assess the imaginative capacity of the use of the kit. The criterion was based on the conception that the metaphorical framing of the kit and its context (narrative), and the narrative-structure associated with the kit, will indicate if the use of the kit or the kit by itself stimulates moral imagination in the user by enabling projection of methods of action and their consequences, and empathetic projection towards others. Based on the results of the evaluation, the expert opinions and user experiences, I inferred that the kit has limited imaginative potential. In the context of collective use in settings such as DIYbio workshops, I argue that imagination required for anticipation of both hard and soft impacts may be triggered based the contextualization of the setting. Whereas in private settings, the kit seems to invoke imagination about (or relevant for the anticipation of) hard impacts rather than of soft impacts.

Following the argument that the imaginative potential of the DIY-CRISPR kit, hence, can be of value in the context of technological assessments relating to CRISPR, I suggest attaching stories to the kit or contextualizing its use in story-like narrative to improve its capacity to evoke imagination about future scenarios and empathy (towards the bacteria or future actors affected by the action). Thus, the use of this improved kit might, I speculate, aid in improving the current ethical deliberations on CRISPR which are largely focused on the hard-impacts.

In addition, I would like to clarify that the claim made about the value of DIY-CRISPR kit in TA, should not be mistaken for the normative arguments that employing the kit is that only way debates on CRISPR can be improved. For instance, different novel scenarios were developed about the non-obvious applications of CRISPR genome editing by participants (mostly biohackers, designers and artists) of the "retreat" organized under the *CRISPR.kitchen*[50] initiative in March, 2017, without the use of any kits like the DIY-CRISPR kit. This case illustrates that the kit is not

[50] The CRISPR.kitchen is promoted by KIT(Karlsruhe Institute of Technology) -ITAS(Institute for Technology Assessment and Systems Analysis)

necessary for building new scenarios. In the context of this particular, however, I could speculate that scenarios were created easily because the participants are experts in the field of DIYbio or biology. This speculation (if true) would reinforce my claim that using the DIY-CRISPR kit in pTA events, with participants from different backgrounds, can improve the ethical deliberations on CRISPR.

Limitations and Recommendations for Future Research

This thesis project, with its very specific and narrow case study of the DIY-CRISPR kit, has few limitations. In this section I will discuss the different shortcomings of my research and suggest directions for future research.

One of the limitations of this research, is that the generalizations and arguments about the imaginative potential of the kit has been based on insufficient empirical data about the users' experiences. The limited scope and time frame for this research prevented me from extensively looking for different users and non-users of the kit. Moreover, it was difficult to find users who were willing to share their experiences with the kit. This drawback may be fixed, I suppose, in future research by either organizing a workshop in which the kit is utilized and later interviewing the participants or by directly getting in touch with the participants of an already conducted workshop. Furthermore, interviewing the non-users of the kit about their reasons for non-use might be useful in analyzing if the kit or its use poses a moral problem.

The lack of sufficient discourse on DIYbio movement and the debates that occur within the movement, from my experience, proved to be a limitation on the research being conducted about the DIYbio movement. This localized niche-like character of the DIYbio movement and its actors, might also be the why individuals and authorities criticize the movement based on biosafety and biosecurity concerns. Hence, as a direction for future research, I would suggest looking into ways to resolve the tension between science and DIYbio, and so, between scientists and biohackers. Further research may also be directed towards understanding why relevant issues raised regarding emerging technologies as part of DIYbio movement do not get reported in academic literature.

A recommendation for future research would be to investigate the relation between play and imagination as well as experimentation (learning by doing) and imagination. Authors like van der Meij, Broerse, & Kupper (2017), for instance, in their research of how to make Responsible Research and Innovation(RRI) reflection practices playful so that it enables learning, draws a link

between playfulness and learning. They consider imagination to be one of the playfulness design elements that should be fulfilled when the purpose of the RRI is to come up with innovative solutions and scenarios. They loosely link imagination and play without providing clear definition for "imagination". Examining what type of imagination is stimulated by play and learning along with how it is evoked, would been beneficial while analyzing the role of activities and objects which are playful and educational.

In relation to the field of moral philosophy and theories of moral imagination, I would recommend future research be focused on discerning the role of non-discursive(non-linguistic) elements such as movies, drama, experiential physical artifacts in stimulating imagination. In moral philosophy, the claims made so far regarding how to cultivate moral imagination (for instance, by Johnson) has been dependent on Nussbaum's theory on the potential of literary works such as novels to stimulate empathy. Coeckelbergh on the other hand extended Nussbaum's theory to mass media like TV news and video games. The sociological research by Holmberg & Ideland, (2016), which I referred to in Chapter III, discussed in brief how bioart evokes ethical response based on the affects that it mobilizes on the spectator. Researches, thus, discussing how movies, tv shows and artifacts would evoke moral imagination would be useful in developing theories on morality.

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ATTRIBUTIONS

Cover Page: Science Lab Research Tests Photo. Photo License: Burst

Figure 1: The development of adaptive defense mechanism in bacteria.
The image has been retrieved from the blog post titled "CRISPR: A game-changing genetic engineering technique" by Pak(2014) is an adaptation from the figures in Barrangou & Marraffini(2014).http://sitn.hms.harvard.edu/flash/2014/crispr-a-game-changing-genetic-engineering-technique/

Figure 2: Info graph on how CRISPR-Cas system can be used to correct defective sequence.
Designed by Joris Fiselier infographics for the report *Editing Human DNA: Moral and social implications of germline genetic modification* by COGEM & Gezondheidsraad. Copyright 2017, COGEM & Gezondheidsraad

Figure 3: Image showing the different components of the DIY-CRISPR kit as used in the ODIN webpage for the product. Copyright 2018, The ODIN. http://www.the-odin.com/diy-crispr-kit/

Figure 4: Screenshot of a part of the protocol for experiment that shows the instructions for making agar plates. Copyright 2018, The ODIN. http://www.the-odin.com/crispr-bacterial-guide/

Figure 5: Image of the DIYbio Code of Ethics drafted by the US and European delegates developed in response to the biosecurity and biosafety concerns raised against the DIYbio movement.
The image has been retrieved from the report "Seven Myths and Realities about Do-It-Yourself Biology" by Grushkin, et al.(2013, p.17), published in November 2013 as part of Wilson Center's Synthetic Biology Project.

APPENDIX A: EXPERT INTERVIEW QUESTIONS

To the experts in the field of Bioart such as Nora Vaage and Agnieszka Wolodzko, following questions were posed:

1. Who is a bioartist and who is a biohacker/DIYbiologist from your perspective?
    - Do you think bioartists should be identified as different from DIYbiologists /biohackers?
2. Do you think there is a relation between bioart and ethics, if so, how would you describe it?
    - how do you think bioartistic practices contribute to ethical discussions surrounding a technology?
3. Based on your observations/experiences, do bioart/DIYbiologists/biohackers have any role in ethical deliberations of a particular technology, say CRISPR? If so, which sort of roles they appear to have?
4. Do you know about the regulatory policies on DIYbio/bioart practices in Europe/ The Netherlands? What are they?
    - Are they different for bioart and DIYbio?
5. What do you consider as the purpose of DIYbio activities and kits? What actual role do they have in practice?
    - Do you think is there a gap between what is aimed for and what is happening in practice?"(for instance , Josiah Zayner said he made the CRISPR kit to democratize science)
    - Is the kit used for that purpose then?
    - How do you think these kits have been used in practice?
6. Do you think the activities performed under DIYbio movement have significance in terms of contributing to ethical discussions surrounding a technology? If so, how?
7. Based on your observations and research, do you think the kits and setups promote imagination of …(potential ways of using of the technology/implications of using the technology/the moral aspects of using it)?
8. What are the new developments and discussions in the field of DIYbio?

- Is the recent introduction of DIY-CRISPR kits different from previous DIYkits? Does its introduction constitute as a major difference to previous /other forms of DIY-bio? If so, how?
- "How much of the debates concerning these developments occur around the ethical concerns? According to you, is this much focus on ethical concerns sufficient?

9. What do you envision as the future of DIYbio movement?

To the experts with hands on experience in biohacking and leading DIYbio workshops like Pieter van Boheemen, Roland van Dierendonck and Lucas Evers, the following questions were posed:

1. What practices in your opinion fall under the phenomenon of DIYbiology? What activities are taking place in the Netherlands?
2. Who are the members/ participants of DIYbio labs in the Netherlands? (Are they just experts in biology?)
3. What is major goal or objective of the DIYbio community labs in the Netherlands (or your lab specifically)?
4. What are the regulatory policies on the DIYbio movement and its activities in Europe and in the Netherlands? How do you make sure that they are followed?
5. What do you consider as the purpose of DIYbio activities and kits? What role would you ascribe to them? Are they simple hobbyist kits or do they have pedagogical role?
6. Do you think the activities performed under DIYbio movement have significance in terms of contributing to ethical discussions surrounding a technology?
7. Do you think the CRISPR kit promote imagination of.... (potential ways of using of the technology/implications of using the technology/the moral aspects of using it)? If so how?
8. What are the new developments and discussions in the field of DIYbio? How important is the ethical debate concerning these developments? Is the recent introduction of DIY-CRISPR kits different from previous DIY kits? If so, how?
9. Do DIYbiologists/ biohackers have/occupy any role in the ethical deliberations of a particular technology, for instance CRISPR, within the scientific community? If so, how would you describe it?
10. What do you envision as the future of DIYbio movement especially in The Netherlands?

APPENDIX B: USER INTERVIEW QUESTIONS

1. Do you consider yourself a biohacker? If so, what feature qualifies someone as a biohacker or a DIY biologist in your perspective? Do you have a background in biology/life sciences?
2. When and how did you hear about the DIY-CRISPR kits?
3. Why did you decide to purchase it?
4. There are several ethical debates and questions posed by CRISPR-Cas9 technology (such as should we allow germline editing because the technology allows to do so? and so CRISPR if implemented properly in clinical settings might completely change our gene pool etc).Were you aware of these ethical discussions and concerns raised in relation to CRISPR technology prior to the purchase and use of the kit?
5. Can you describe what you did with the kit? How was your experience using it? What were your thoughts about using it, both during and after use?
6. What can you say about the instructions/protocols that came with the kit? What did you think about them? Did you watch any videos on how to use the kit?
7. Were you able to successfully complete the experiment and achieve the shown result? Did it happen on the first trial?
8. Would you recommend others to use the kit, and why (not)? If so, are there any specific groups in particular that should use it, and why?
9. Did using the kit make you think about the possibilities and potential of the CRISPR-Cas9 technology? If so, how? Did you discuss these topics with others (if so, who and what was discussed)?
10. To what extent do you think DIYbio movement and biohacking practices should be regulated (in terms of being watched over by government or banned due to biosafety risks may be)?