Designing a tool to stimulate reflexivity of fundamental scientists using a novel co-design approach

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NUCLEUS

DESIGNING A TOOL TO STIMULATE REFLEXIVITY OF FUNDAMENTAL SCIENTISTS USING A NOVEL CO-DESIGN APPROACH

By

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“If you do what you always did, you will get what you always got”

- Albert Einstein

ABSTRACT

Following the perspective of the European Horizon 2020 project 'NUCLEUS', Responsible Research and Innovation (RRI) should be brought to life in universities and scientific institutions. This study acts as one of the mobile nuclei of the NUCLEUS project, with the goal to operationalize RRI instead of building theories. The aim of this research is to stimulate reflexivity, one of the dimensions of RRI, amongst scientists in fundamental research within the TU Delft, using a simple tool or method. This is done using a self-developed co-design approach, based on design-based research. This research is the first attempt to create a tool together with the end-users, the fundamental scientists, to stimulate RRI.

In this study, the mirror tool is designed and tested. On micro-ethics level (first order) reflexivity was stimulated using the tool. Especially first year's students mentioned that the mirror form would help guiding them when reflecting on large projects or when being stuck. However, macro-ethics (second order reflexivity) was not considered using the tool, and thus the socio-ethical and socio-economic aspects were not taken into account yet. Therefore, changes to the design are proposed assuring also macro-ethics will be considered.

Using the tool, not only reflexivity is stimulated, but also responsiveness is encouraged, due to the last question 'So what?'. In this way, not only learning and thinking will change, but also adjustments can be made to the current way of working.

Implementation of the tool at the BN department of the TU Delft could be done via two ways: either via the graduate school or via the principle investigators. Furthermore, quantitative tests should be performed to statistically prove the effect of the tool, increasing its reliability. Besides, the tool could be more functional when digitalizing the mirror form, such that users are not limited by the amount of writing space and such that supplementary elements could be implemented.

Apart from using the mirror tool in their universities, the NUCLEUS consortium can additionally benefit from the new methodology to create a tool for RRI with and for scientists. Using the one page guideline (appendix 17), consortium members can conveniently create a tool for RRI for their specific target group and in their context.

ACKNOWLEDGEMENTS

During my master thesis project at a fundamental research group at the TU Delft, I was surprised that there was not a lot of attention for Responsible Research and Innovation (RRI) of PhD students. Therefore, I wanted to create a simple and useful tool for fundamental researchers stimulating RRI.

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CONTENT

LIST OF ABBREVIATIONS

AREA	Anticipate, Reflect, Engage and Act
BN Department	Bionanoscience Department (of the Technical University Delft)
ELSA	Ethical, Legal and Social Aspects
H2-questions	'How to?' - questions
NUCLEUS	New Understanding of Communication, Learning and Engagement in Universities and Scientific institutions
P#	Participant number #
PhD student	Doctoral student
PI	Principle Investigator
R&D	Research and Development
RRI	Responsible Research and Innovation
STIR	Socio-Technical Integration Research

1. INTRODUCTION

1.1 GENERAL INTRODUCTION

Over the last decade, Responsible Research and Innovation (RRI) catapulted from an obscure phrase to a major topic in the European Commission's Horizon 2020 program (Rip, 2014). As Stilgoe (2013) describes: "Responsible innovation means taking care of the future through collective stewardship of science and innovation in the present". To move a step forward, it is necessary to look at the present state.

In 2016, NUCLEUS, New Understanding of Communication, Learning and Engagement in Universities and Scientific institutions, started as a European Horizon 2020 project to bring RRI to life in universities and scientific institutions (Gerber, 2014) (figure 1). Instead of building theories on RRI, the goal is to operationalize RRI. Next to the ten embedded nuclei, operationalizing RRI is done by twenty smaller projects, the mobile nuclei. In these projects RRI activities will be integrated in events to aim for the uptake of RRI by a wider audience. This research project acts as one of the mobile nuclei within the TU Delft.

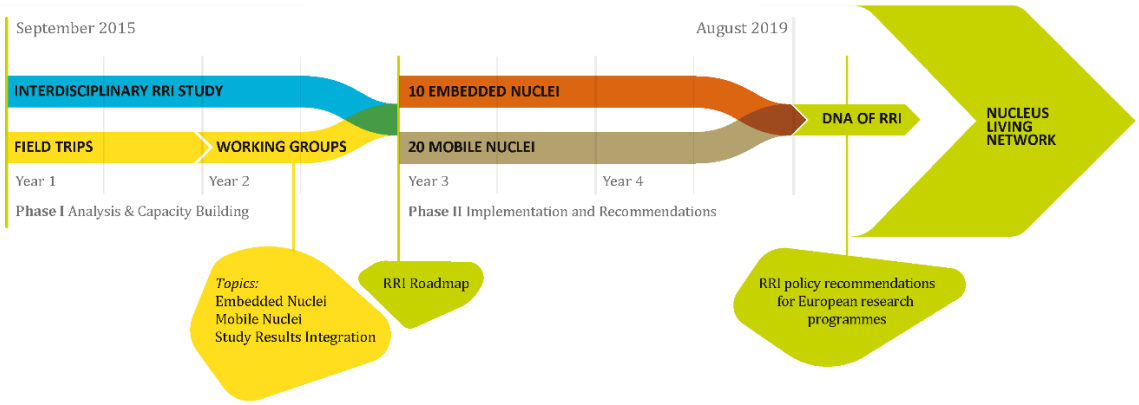


FIGURE 1: PLANNING OF THE NUCLEUS PROJECT. THIS STUDY IS DONE DURING YEAR 3 OF THE PROJECT.

Four core dimensions of responsible innovation have been articulated: anticipation, reflexivity, inclusion and responsiveness (Stilgoe, Owen, & Macnaghten, 2013). This framework was designed to be used by the UK Research Councils and the scientific communities that they support. The focus of this project will be on reflexivity, since this is the most suitable dimensions for the target group, fundamental scientists.

Previous studies show that midstream modulation was a useful method for enhancing reflexivity (Fisher, Mahajan, & Mitcham, 2006; Flipse, van der Sanden, & Osseweijer, 2013a; Schuurbiers, 2011). Midstream modulation is the working principle of Socio-Technical Integration Research (STIR), where an embedded humanist cooperates with scientists to engage them with the social and ethical relevant aspects of their work (Flipse & Bayram-Jacobs, 2016; Flipse et al., 2013a; Richard Owen et al., 2013). This is a laborious method that takes up to several weeks to execute. For this reason, the aim is to investigate simpler alternatives.

Besides midstream modulation, co-design is important for a successful intervention, since changes should be initiated by the users (Fisher et al., 2006). In this way, scientists are involved in an early stage in the societal aspect of their research, which can create shared value (Lee, Olson, & Trimi, 2012). This is in accordance with the vision of the NUCLEUS project, ensuring the development of innovative

strategies and practical recommendations in a co-building mode, ensuring co-responsibility and complementary roles of all partners within the project (Flipse & van der Sanden, 2016).

Until now, RRI has been focussing on applied science. However, this research focusses on PhD students within fundamental science. In fundamental research no end product is involved; instead its goal is to expand knowledge. Even though the focus is not on the end project, raw materials are provided for possible high impact future developments. Besides, mostly senior researchers come in contact with RRI, when applying for grants. PhD students most often do not write their own proposals for applying grants, meaning they are less forced to think about the ethical aspects of their work. Moreover, it is important to implement RRI in workflow as young as possible. Therefore, the target group of this research is on PhD students in fundamental research.

This research is the first attempt of using a co-design method in creating a tool or method for stimulating responsible research and innovation together with the end-users, the fundamental scientists. Due to the recent start of the research area of RRI, this was never done before, as normally a tool or method would be designed by social scientists and only tested with the end-users.

1.2 RESEARCH QUESTIONS

The aim of this research is to design and test a simple tool or method, via a novel co-design method, to stimulate reflexivity of fundamental researchers within the TU Delft in the context of Responsible Research and Innovation. This starts from the perspective of operationalizing Responsible Research and Innovation theories and is part of the focus of the Horizon 2020 project “NUCLEUS”. This aim will be reached by answering the following research question:

To what extent can reflexivity amongst PhD students in fundamental research within the TU Delft be stimulated with a simple and sustainable tool or method?

This ‘simple’ tool can be defined by being not laborious and easy to use. In this way, the fundamental scientists can understand and use the tool or method without the help of social scientists, unlike the previously mentioned STIR method. Besides, in this context, sustainable means that the scientists consider the tool as useful, so they will keep using it after introduction of the tool. This research question is supported by four sub-questions, which will be answered by interviews, observations, literature and a test including a group interview.

1. *To what extent is reflexivity a suitable dimension of Responsible Research and Innovation for fundamental scientists?*
2. *What motives do fundamental scientists have for being reflective or not?*
3. *Which methods or tools for increasing reflexivity are currently available?*
4. *How does a co-design approach help in creating a tool stimulating reflexivity?*

Following the research question and the limitations of this study, five requirements were formulated for the design of the tool: The tool should stimulate reflexivity of fundamental scientists; The tool should be considered as useful by the scientists; The tool should be implemented at the BN department of the TU Delft; Creating the tool should be feasible within the available time of a master thesis project; Creating the tool should be feasible within the financial means. These criteria were used to select the most suitable concept in the co-design session.

2. BACKGROUND

In this background section context is provided for the research question and its sub-questions. Besides, sub-question 3, 'Which methods or tools for increasing reflexivity are currently available?', is answered. Also, the other sub-questions, regarding reflexivity as a proper dimension for RRI, researchers motives for reflexivity and a co-design method, are partially answered in this background section.

2.1 RESPONSIBLE RESEARCH AND INNOVATION

To investigate to what extent reflexivity matches with fundamental scientists as a proper dimension for RRI (sub-question 1), context should be provided on RRI. Besides, the dimensions of RRI are explained and researchers motives and reservations on RRI are described (sub-question 2).

2.1.1 What is Responsible Research and Innovation?

In the last decade, Responsible Research and Innovation became an important phenomenon on the European Union agenda (Rip, 2014). The objective of RRI is that scientists will see embedding their research in society as part of their professional responsibility (Rip, 2014). In other words, scientists need to take the ethical and social controversies into consideration during their daily work. Von Schomberg (2013) defined Responsible Research and Innovation as "a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society)".

It is difficult to predict the societal impact of science and technology. Therefore, early societal intervention is necessary to avoid failed embedding in society of technological advances. Also, it can help governing and exploiting the positive and negative impacts at a much earlier state. Products need to be reflected on three anchor points already mentioned in the definition of RRI of Von Schomberg (2011). First of all, the research or innovation needs to be (ethically) acceptable, which refers to the values and rights and safety protection. Secondly, it should be sustainable, including economic, social and environmental dimensions. Lastly, the research or innovation should be socially desirable, according to the norms and values of the EU (von Schomberg, 2011). In this way, the roles of scientists need to be changed concerning embedding in society (Rip, 2014).

2.1.2 History of RRI

Before RRI, the term ELSA (Ethical, Legal and Social Aspects) was used. Key in this concept was interaction between societal actors and innovators, which is also a key element for RRI. However, ELSA focused solely on the negative consequences at the end stage of innovation. In the context of the EU funding initiatives the term Responsible Research and Innovation was initiated. This shift to RRI was introduced by science policy makers in a top down matter. In RRI, economic valorisation is given more prominence (Zwart, Landeweerd, & van Rooij, 2014). More emphasis is now on collaboration with industry and socio-economic benefits. However, the concept of RRI still lacks clarity (R. Owen, Macnaghten, & Stilgoe, 2012), resulting in difficulties in practical implementation (Burget, Bardone, & Pedaste, 2017).

2.1.3 Dimensions of RRI

Responsible Research and Innovation consists of multiple dimensions, however different formulations of dimensions are defined. For example:

- The AREA-framework (Engineering and physical sciences research council, 2018), considering "Anticipate, Reflect, Engage and Act".
- The framework of Owen (2013) regarding "anticipatory, reflective, deliberative and responsive [actions]" (Richard Owen et al., 2013).
- The RRI-tools framework (RRI tools, 2018) with terms like "open & transparent, reflective & reactive and inclusive".
- The framework of Stilgoe et al. (2013) including the four dimensions anticipation, reflexivity, inclusion and responsiveness (Stilgoe et al., 2013).

In this research, the framework of Stilgoe et al (2013), is used, since this is the most commonly used framework. This framework was designed to be used by the UK Research Councils and the scientific communities that they support. In the next paragraphs, each dimension (anticipation, reflexivity, inclusion and responsiveness) will be explained separately.

First of all, anticipation describes "What if?" to consider future scenarios of research and innovations. A foresight in issues concerning science and innovation is used to predict and shape a desirable future. Therefore, anticipation is a combination of prediction, which means identifying possible futures, and participation, meaning opening up possible futures (Stilgoe et al., 2013). Anticipation plays an important role at the emergence of innovations as it serves the purpose of reflecting on the implications of the product or project, being clearer about uncertainties, opening the visions to a broader public and using these outcomes for shaping the trajectory of the innovation. Therefore, anticipation directs a researcher to a more desirable outcome (Burget et al., 2017). Timing of anticipation is very important: it plays an important role at the start of the project. However, anticipation should be applied late enough to be meaningful (Burget et al., 2017). Anticipatory discussions of possible desirable futures can be started through techniques like "upstream public engagement" (Wilsdon & Willis, 2004) and "Constructive Technology Assessment" (Schot & Rip, 1997).

Secondly, reflexivity means reflecting on your own activities, commitments and assumption and trying to rethink prevailing conceptions. Essentially, it is holding a mirror up to one's own work and beliefs, keeping in mind your limits of knowledge and framing of the issue. Therefore, it asks scientist to blur the boundary between their role and moral responsibilities, which requires an open culture (Stilgoe et al., 2013). Previous studies show that "midstream modulation" was a useful method for enhancing reflexivity (Fisher et al., 2006; Flipse et al., 2013a; Schuurbiers, 2011).

Besides, inclusion is an important aspect of RRI, meaning to involve other stakeholders as part of a search for legitimacy (Stilgoe et al., 2013) and identifying socially desirable outcomes (Von Schomberg, 2013). To enable public debate, small-group processes of public dialogue, called 'mini-publics' can be organised (Goodin & Dryzek, 2016). Quality of dialogue for inclusion must be ensured by intensity and openness. However, involving the public is also criticized, especially on framing the issue. This can reinforce effects of professional power and deficit understanding of the public (Kerr, Cunningham-Burley, & Tutton, 2016). Inclusion is seen as the dimension that characterizes RRI the most. However, inclusion requires more reflection and critics (Burget et al., 2017).

Lastly, responsiveness can be described as reacting on changing circumstances by changing direction of the innovation (Stilgoe et al., 2013). This gives a response to the questions raised and improvements made by the above three dimensions. Especially, responsiveness is linked to anticipation and transparency (Burget et al., 2017). A mechanism for responsiveness can be "widened technology assessment and foresight" (Von Schomberg, 2013) or "value-sensitive design" (Friedman, 1996).

2.1.4 Modulation

Intervention for Responsible Research and Innovation can be done at three different moments: upstream, downstream and midstream (figure 2).

Upstream engagement takes place when funding decisions are made, but before scientific results are gathered. Therefore, it tries to shape the trajectory of research and development (Fisher et al., 2006). An example of upstream regulation is technology assessment.

Downstream regulation is a post-research and development stage, occurring after the scientific results are gathered and translated into products. An example of this is setting up regulations and market mechanisms (Fisher et al., 2006).

Midstream modulation takes places 'before scientific result are translated into products and services, but after authorization and funding decisions have been taken' (Schuurbiers & Fisher, 2009). Midstream modulation is a more reflexive participation than upstream or downstream engagement, occurring during the research and development phase of the project (Fisher et al., 2006). The goal of midstream modulation is to 'elucidate and enhance the responsive capacity of laboratories to the broader societal dimensions of their work' (Schuurbiers, 2011). This modulation is done during ongoing laboratory practices. In this way, social and ethical dimension can be taken into account during the research phase. Based on this feedback, the direction of research can be shifted towards a more responsible research. Midstream modulation can be applied as a form of socio-technical integration research (STIR) (Schuurbiers, 2011) or sensitization (Penders, Vos, & Horstman, 2009). Since this study is focussed on PhD students, the focus of the tool will be on midstream modulation.

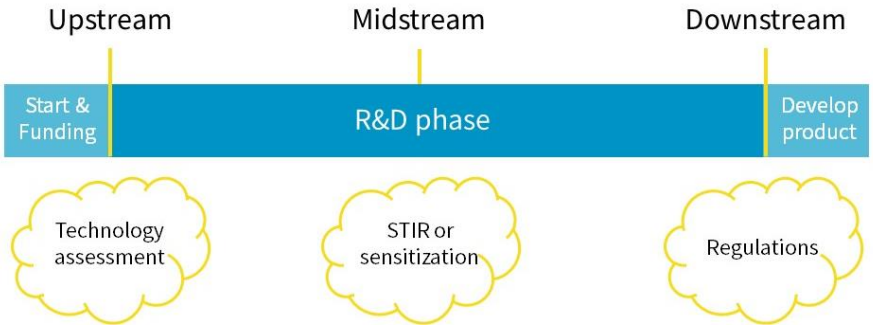


FIGURE 2: OVERVIEW OF UPSTREAM ENGAGEMENT, MIDSTREAM MODULATION AND DOWNSTREAM REGULATION ON A TIME SCALE.

2.1.5 Quality criteria RRI

Quality criteria for RRI are described in two different ways: (1) In line with the four dimensions of RRI (Stilgoe et al., 2013) and (2) based on the RRI policy agendas Governance, Science Education, Open Access, Ethics, Public Engagement, Gender Equality, Sustainability and Social Justice (Expert Group on Policy Indicators for Responsible Research and Innovation, 2015). Since in this project the four dimensions of RRI are used, only these design requirements are elaborated on.

Kupper et al (2015) described a set of quality criteria of RRI in line with the four dimensions. Four clusters of requirements were defined: Anticipation and reflection; Diversity and inclusion; Openness and transparency; Responsiveness and adaptive change (Kupper, Klaassen, Rijnen, Vermeulen, & Broerse, 2015).

Anticipation and reflection are the core criteria for taking responsibility for research and innovation. To be able to anticipate, not only the future should be envisioned but also the present should be reflected (Kupper et al., 2015). The process requirements of anticipation and reflection are split in five criteria: analysis of the background, current situation and context of the research or innovation; envisioning of plausible futures; variety of impacts; facilitating deliberation on values perceptions, needs, interests, choices, and definition of the problem at issue in the practice; and addressing roles in responsible innovation trajectories. The first and fourth criteria are linked to (first order) reflection and will be used as design criteria for the creation of the tool.

Diversity and inclusion are criteria to support the vision that science is not only done for society, but also with society. These criteria are broken down into five main criteria: Engaging a variety of stakeholder groups, variety in the sense of stakeholder engagement, engagement of publics, institutional diversity and attention for appropriate research and innovation models and methods (Kupper et al., 2015).

Openness and transparency are at the basis of creating mutual understanding between the stakeholders. In this way, clarity about responsibilities is created. Five main criteria are formulated to support this requirement: Honest and clear representation of the practice details, open and clear communication about the processes of deliberation and decision making, open and clear communication about the results of the practice, appropriate means and content of communication and education per actor and openness to critical scrutiny from all stakeholders (Kupper et al., 2015).

The last criteria are responsiveness and adaptive change. These criteria are necessary to stimulate researchers to open up for changing circumstances and act according to this. This is therefore the final step for RRI, taking action. For this, six criteria are defined: structure for seeking and incorporating feedback, flexible process management, development and implementation of evaluation strategies, flexible attitudes to revise views and actions, changing responsibilities and application of results (Kupper et al., 2015).

2.1.6 Researchers' motivation for RRI

Researchers can have several motivations for implementing RRI. Three forms of motivations of researchers are identified: normative, instrumental and substantive motivation (R. Owen et al., 2012).

Normative motivation is when people think something is the right thing to do for reasons of democracy, equity, equality and justice (Sykes & Macnaghten, 2013). Researchers carry social responsibility and moral duty. To consider social and ethical aspects in their work, researchers should recognize and reflect on these aspects. This should lead to a more transparent and accountable decision making process during research and development (Flipse, van der Sanden, & Osseweijer, 2013b). However, researchers have difficulties identifying the social impact being unaware of the broader social and ethical context. Reflection could have effect on research and development practice and therefore, obtaining skills to reflect on social and ethical aspects could be useful and relevant. This

could place the researcher in a wider societal frame, motivating them to consider these social and ethical aspect and thus RRI (Flipse et al., 2013b).

Instrumental motivation relates to ways of building trust or avoiding adverse public reaction (Sykes & Macnaghten, 2013), which is called the societal perspective by Flipse et al (2013b). As academic research is largely paid by the public and the innovations affect society, researchers feel responsible for publics concerns. Therefore, researchers need to know societal considerations and concerns (Flipse et al., 2013b). This can be done by communicating their activities and findings, so societal actors can estimate its impact (Stirling, 2008).

Lastly, substantive motivation aims at achieving generally better ends (Stirling, 2008). This motivation is in line with the R&D perspective of Flipse et al (2013b). Researchers can have the motivation for RRI if they consider societal and ethical aspects improving the quality of their research. Public influence can help shaping R&D which can prevent unwanted innovations, but can also stimulate more successful innovations (Flipse et al., 2013b). It can also stimulate researcher's creativity and helps with planning (Fisher et al., 2006).

2.1.7 Researchers' view and reservations on RRI

In the above section, the motivation for RRI are being discussed. However, also reservations are found. Several recent studies have been performed to investigate the view of researchers on RRI and their reservations. In this paragraph three of them will be described.

According to Emad Yaghmaei, a researcher focussing on RRI at the TU Delft, four groups of declining RRI can be distinguished: The first group declines the importance of RRI, the second group does not see it as an important strategy, the third group thinks RRI is important, but not urgent and the last group thinks RRI is important but they do not have resources to apply RRI.

Previously in the NUCLEUS project, interviews were conducted with leading researchers and research executives to gain insights in researchers' view on RRI and barriers to its implementation (Böger, Carrier, Gartzlaff, & König, 2017). In this research, the overall attitude towards RRI was positive, considering RRI as important. Input from stakeholders was welcomed, although concerns on the reputation of science were expressed when involving companies. Besides, involving the public, especially in the direction from science to the public, was welcomed. However, there were three kinds of reservations about RRI.

First of all, it depends on which field, how useful RRI is considered by scientists. In application-oriented sciences, RRI could be very useful for getting input from outside of science. However, fundamental research is viewed as not socially relevant. Scientists believe the distance between the research and the public is too big for meaningful input and fundamental research should proceed without intervention. However, several leading researchers stated that RRI should also pursue basic research, as this lays foundations for successful future applications. Secondly, some scientists were concerned non-scientists were uninformed on the research and therefore could not provide useful input. The third reservation was that scientists were afraid RRI will become another bureaucratic layer, taking away time for addressing other challenges (Böger et al., 2017).

Besides, students of the Science Communication master program of the TU Delft conducted interviews with researchers from the TU Delft on their vision on RRI, in particular inclusion, and concluded that

there was a lack of awareness, interest and activity for RRI as well as for inclusion. Eight applied physics post-docs were interviewed on RRI activities and especially inclusion activities. For these post-docs, doing research was the most important activity and engaging in inclusion activities would take away their time to do research. Besides, they found that current RRI and inclusion related activities were limited (Keutel & van Hattum, 2017).

Another group of Science Communication master students focused on what elements of RRI are being perceived as a possible barrier or as a useful practice (Smeets, Baas, & de Jong, 2017). Seven researchers of four different fields of study were interviewed and they found three factors influencing researchers to apply RRI: intrinsic motivation, the field they work and formal guideline of the institution. These results are in line with the results from the NUCLEUS research on researchers' view on RRI (Böger et al., 2017). Researching the four pillars of RRI, they found that the researchers do not apply anticipation: "They often think their work will not have a direct impact on society and the work they do is ethically neutral." (Smeets et al., 2017). Researchers sometimes apply responsiveness, taking feedback into account of their colleagues and scientific world, which also applies for inclusion. Reflexivity was not applied by the researchers, as they did not know anything about the formal code of conduct.

In summary, scientists think RRI is important. However researchers do not apply RRI mostly due to the following reasons: Scientists think non-scientists are uninformed on the research and therefore could not provide useful input, the field they work (for example fundamental sciences) is not suitable for RRI and another bureaucratic layer will be added by RRI. The tool created in this research needs to be evaluated on these factors.

2.2 Reflexivity

This research focuses on only one of the dimensions of responsible research and innovation: reflexivity. This dimension is chosen as it was thought to be the most relevant for fundamental scientists. Fundamental scientists are far away from the application part of research. Therefore the dimensions anticipation and inclusion are less relevant. Furthermore, responsiveness can be the result of reflexivity, since to determine what choices will lead to ethical, socially desirable and sustainable futures, one should first reflect on the current situation and the potential future (Flipse et al., 2013b).

To answer the research question "To what extent can reflexivity amongst PhD students in fundamental research within the TU Delft be stimulated with a simple and sustainable tool or method?", first a clear definition of reflexivity was formulated. Besides, reflexivity of fundamental scientists is discussed. Afterwards, criteria for reflective thinking are elaborated on.

2.2.1 What is reflexivity?

In the previous section, reflexivity was already shortly described as 'reflecting on your own activities, commitments and assumptions, trying to rethink prevailing conceptions' (Stilgoe et al., 2013). In this way, scientists can consider their roles and responsibility, and awareness is being raised for framing issues and suggested solutions (Zwart et al., 2014). Values and beliefs are being reflected on during research and development (Burget et al., 2017). Dewey (1933) even states that the roots of reflection are in scientific inquiry, being a systematic and disciplined way of thinking (Dewey, 1933).

Two orders of reflexivity are being determined according to Wilford (2015). First-order reflexivity concerns adaptations or changes in the process or technology in such a way that a problem can be identified and fixed. Second-order reflexivity concerns reflecting on someone's own norms and values within the system (Schuurbiers, 2011). Therefore, it takes the framing in which the work is done into account, whereby researchers take responsibility for the assumptions that guide their actions (Wilford, 2015). Midstream modulation supports both first- and second-order reflexivity (Schuurbiers, 2011). In this way, researchers will become aware of what they are doing and why they are doing so, but also will reflect on ethical and social aspects. Finlay (2002) states that reflexivity offers a tool for scientists to analyse how subjective elements influence their research by becoming self-aware.

Reflexivity can be applied to micro-ethics and macro-ethics. In micro-ethics normative issues are discussed concerning "individuals and internal relations of the engineering profession" (Herkert, 2005), resembling first-order reflexivity (Schuurbiers, 2011). In macro-ethics "the collective social responsibility of the profession and to societal decisions about technology" (Herkert, 2005), similar to second-order reflexivity (Schuurbiers, 2011). For example, in natural sciences an issue concerning micro-ethics could be questioning the way an experiment is done. In macro-ethics, the bigger ethical questions are taken into account considering ideals of a person, like making decisions based on ethical motives.

Previously, reflexivity was stimulated using collaborative approaches (such as midstream modulation) and public dialogue. Involving the public in research will help researchers to reflect on ethical and social dimensions of their work (Burget et al., 2017). For example, social scientists and philosophers can be involved in laboratory processes to promote active reflexivity. This can be explained by the theory of social learning (Wenger, 2000). When acting at the boundaries of knowledge, competence and experience tend to converge. People are being exposed to foreign competences, which will stimulate learning.

2.2.2 Reflexivity of fundamental scientists

As mentioned in the previous section on RRI, research of NUCLEUS concluded that leading researchers have reservations on the combination of RRI and fundamental research (Böger et al., 2017). It was stated that fundamental research should proceed freely and without intervention. Therefore, the input of lay people or stakeholders would not be meaningful, because of the distance between fundamental research and public needs. However, the research of Böger et al. (2017) primarily sees RRI as the dimension inclusion and not reflexivity. In this research, the focus is on reflexivity of fundamental scientists and not inclusion.

2.2.3 Criteria of reflective thinking

Almost 100 years ago, Dewey (1933) articulated four criteria for reflective thinking, described by Rodgers (2002). First of all, reflection is a meaning-making process. This means, connections can be made between experiences for deeper understanding. Secondly, reflection is a systematic rigorous, disciplined way of thinking. Thirdly, reflection needs to occur in interaction with others. Lastly, reflection requires attitudes that value the personal and intellectual growth of oneself and others. (Dewey, 1933) (Rodgers, 2002).

Van der Meij et al (2017) identified three essential process conditions for learning and reflection. First of all, this is the need of experimentation space including openness, elimination of initial judgement and freedom to make errors, voluntariness, time abundance and flexibility in the process structure and

order. This supports “the creation of a multitude of diverging thoughts and actions” (van der Meij, Broerse, & Kupper, 2017). Secondly, focus is being essential for playfulness, meaning expectations throughout the project should be made clear. This can be due by facilitating sub-tasks and simplifying the learning content. In this way, deeper reflection is facilitated. Lastly, stimulating guidance is necessary in playful learning contexts. This includes personal attention, rewards and feedback. This results in increased motivation and engagement of learners.

Besides, Flipse et al (2013) set up requirements of successful integration of social and ethical aspects in R&D practise. First of all, the interventions should be done in the R&D phase (Flipse et al., 2013b), called midstream (Fisher et al., 2006), since here the researchers’ influence is probably the largest. Besides, the integration of social and ethical aspects need to be done during decision making processes. Furthermore, support or reward of the organisation is necessary to include social and ethical aspects in the work of the researchers. Lastly, the introduction of social and ethical aspects in the work of researchers need to be done in three phases: creating awareness, being reflexive and lastly actively use the social and ethical aspects in R&D (Flipse et al., 2013b).

The above mentioned criteria will be taken into consideration in the designing process of the tool.

2.3 CURRENT TOOLS FOR INCREASING REFLEXIVITY

Since the goal of this research is to design and test a simple tool or method, via a co-creation process, to increase the reflexivity with regard to social ethical context of fundamental researchers within the TU Delft, current tools concerning reflexivity were evaluated, which will give answer to sub-question 3. Only tools modulating midstream are considered, since this is the aim of this research.

2.3.1 RRI tools

To translate RRI guiding principles into an overview of best practises, an European Union project, the RRI tools project was launched (Groves, 2017). The result of this project is a website (www.rri-tools.eu) where best practices of RRI including implementation tools, RRI tackling projects, inspiring practices and other documents on RRI are bundled (figure 3). Using a search engine, suitable projects, tools and documents can be found. Entering the term “reflexivity” and checking “tool” and “useful for research community”, the only tool popping up is the STIR method, described below. Besides, documents of reflexivity were found using these search terms (without checking “tool”), such as a review paper on RRI definitions (Burget et al., 2017) and on mapping social responsibility including the reflexivity rationality (Glerup & Horst, 2014), used in this background section. The goal of the RRI-tools website is wide dissemination of RRI (figure 3).

The website of RRI tools also includes a self-reflection tool in which reflection can be done on ethics, gender equality, governance, open access, public engagement and science education. In this way, institutions can reflect on their organisation on several levels. However, I am only aiming at a small part of this, so this is less relevant for my research. A RRI development plan is attached to the tool, which can be useful setting up RRI activities, tools or methods.

FIGURE 3: GOALS OF RRI TOOLS WEBSITE (WWW.RRI-TOOLS.EU), A EUROPEAN UNION PROJECT. ON THE WEBSITE, AN OVERVIEW IS GIVEN OF THE BEST PRACTICES IN RRI.

2.3.2 STIR

Midstream modulation is the working principle of Socio-Technical Integration Research (STIR), which is a collaborative approach of researchers of natural sciences and social sciences to stimulate Responsible Research and Innovation (Stolk, Fisher, & Flipse, 2016). Reflexive learning is being stimulated by STIR, leading to a practical value. For a period of twelve weeks a social scientist, acting as an embedded humanist, cooperates with natural scientists to engage them with the social and ethical relevant aspects of their work (Flipse & Bayram-Jacobs, 2016; Flipse et al., 2013a; Richard Owen et al., 2013). An embedded humanist is a functional member of the group, acting as an observer and advocate. STIR should be carried out voluntary (for the researchers), open-ended, structured and systematic (Stolk et al., 2016).

To structure the reflection of ongoing social processes, a decision model was designed (Fisher, 2007), consisting of four iterative components. The first component is opportunity, being a situation eliciting a response. This could be found out by asking the question “What are you working on?”. The second element is considerations, being selection criteria enabling or constraining, potentially influencing the response to the opportunity. These considerations could be split up in human, social and material considerations, found by asking “Why are you working on in?”. The third component alternatives, being perceived options in response to the opportunity, could be found by asking “How could you approach it differently?”. Lastly, the component outcomes is used in the decision model, being the decision as a response to the opportunity, asking “Who might be affected in the future?”. (Fisher, 2007; Richard Owen et al., 2013)

Previous research showed a “productive research disruption” resulting in changes in their decision-making by STIR (Richard Owen et al., 2013). Participating researchers showed to become more reflexively aware of socio-ethical contexts of their work and these changes in reflexivity could lead to changes in materiality. Voluntary changes in the decision process and the nature and direction of their work were observed (Fisher & Schuurbiers, 2013).

As (Fisher & Maricle, 2014) state, socio-technical integration is “any process by which technical experts account for the societal dimensions of their work as an integral part of this work”. This means, midstream modulation can be applied by collaboration between a social scientist and a natural scientist, but this is not a prerequisite. Therefore, I want to reduce this laborious method of interacting

through several weeks and design a tool which is less laborious and simple to use for the natural scientists, still stimulating reflexivity.

2.3.3 Sensitization

Reflection can also be invoked by sensitization (Penders et al., 2009). This means letting both natural and social scientists experience each other's worlds. Therefore, the boundaries between science and society are being crossed. It needs a lot of effort of both the natural scientists and the social scientists to make this happen. Since sensitization occurs midstream, changing the course of research is still possible after reflecting on the practices.

2.3.4 Research Diary

In the research of Nadin and Cassell (2006) a research diary was applied in management research as a tool to aid reflexivity in the research process. It was shown the diary was a valuable tool. Using a research diary provided time, space and context to be reflexive. It was suggested all researchers should systematically use a research diary (Nadin & Cassell, 2006). Therefore this could also be a useful tool to stimulate reflexivity of fundamental natural scientists. However, when working as a bachelor and master student in the labs of biotechnology and nanobiology at the faculty of applied sciences at the TU Delft, I experienced a research diary was already widely used. Therefore, this is already implemented at the TU Delft.

2.3.5 Playfulness

Another current method for stimulating effective learning and reflecting is applying playfulness. Playfulness "helps people to learn and to perform complex tasks" (van der Meij et al., 2017) and therefore this helps coping with uncertainties of RRI. In this way, it stimulates an curious, flexible, inventive and prejudice-free attitude to analyse new information and synthesize new ideas or solutions.

Four activity principles of playfulness were found: narration, imagination, action-reflection and co-creation. Narration stimulates reflective thinking by exchanging information by sharing and hearing a story. Also, personalization of the story by narration enables learners to identify themselves with the content. The effect of narration is engagement by empathy, looking at other perspectives than of themselves. Imagination stimulates making the unknown more tangible and extracting multiple viewpoints. This could be done by using ambiguous objects or brainstorming. Action-reflection is based on an action followed by the consequences or feedback needed for reflection, facilitating consequential thinking. In this way, the action can be tuned toward a better action. Lastly, co-creation stimulates reflective thinking by collaborative creativity, helping social learning (Wenger, 2000). These activity principles can serve as design elements facilitating reflection processes.

2.3.6 Real-time technology assessment

The last midstream method to stimulate reflexivity is real-time technology assessment (Guston & Sarewitz, 2002). This method consists of four components. The first component is the development of similar case studies to understand and anticipate on societal responses to innovations. The second component is research program mapping to identify key research and development trends, stakeholders, organizational structures and relations. In this way, it could be understood "what is going on". The third component consists of communication and early warning, to determine the complex societal relation with innovation, like analysing media sources for public communication, public concerns and its reaction. In this way, the quality of communication of developments is enhanced. The

last component is technology assessment and choice, to identify the societal impacts (Guston & Sarewitz, 2002).

In this way, this method stimulates efforts to enhance desirable impacts and redirect undesirable impacts since the method is done midstream. Therefore, greater concordance between the public and the innovations are reached.

2.4 CO-CREATION

The main goal of this project is to create a tool to stimulate reflexivity of fundamental scientists. This should done in a co-designing mode, trying to figure out how this method would help creating a tool for reflexivity (sub-question 4). This is in line with the aim of NUCLEUS, New Understanding of Communication, Learning and Engagement in Universities and Scientific Institutions. Their aim is: "… to develop innovative strategies and practical recommendations in a co-building mode, ensuring co-responsibility and complementary roles of all partners within the project" (Gerber, 2014).

Co-creation means creation shared by two or more people or collective creativity (Sanders & Stappers, 2008). Since such collaborative processes require negotiation and different perspectives are introduced, mutual understanding is created. This produces alignment and joint responsibility (van der Meij et al., 2017). Also, the consumers point of view is highlighted and needs and wants are identified, which create shared value (Payne, Storbacka, & Frow, 2007). Besides co-creation, value is also created by personalized experiences (Prahalad & Ramaswamy, 2004).

2.4.1 Co-design

Co-design is a form of co-creation, where co-creation is applied along a process of designing (Sanders & Stappers, 2008). Three roles can be found in a co-design process (figure 4). First of all, the person who will be served, the expert or user, plays a large role in knowledge, idea and concept development. Secondly, the researcher plays a role by providing tools for ideation and expression. Lastly, the designer will give form to the ideas of the expert (Sanders & Stappers, 2008).

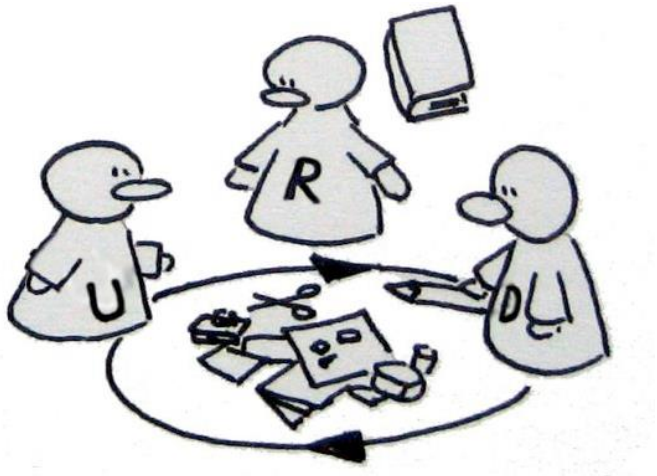


FIGURE 4: THE CO-DESIGN METHOD INCLUDING THE THREE ROLES OF USERS (U), RESEARCHERS (R) AND DESIGNERS (D). ADAPTED FROM (SANDERS & STAPPERS, 2008)

Steen et al (2011) found many benefits of co-design. For example, higher satisfaction and higher loyalty of customers was found, which can help with the implementation of the product. Furthermore, the quality was higher and more successful innovations were founded (Steen, Manschot, & de Koning, 2011).

It depends on the level of creativity and expertise of the user to what extent they can act as an co-designer (Sanders & Stappers, 2008). Four levels of creativity are defined: the creating type is motivated on inspiration, the making type is motivated by asserting an ability, the adapting type is motivated by appropriation and the doing type is motivated by productivity. The researcher should give them the appropriate tools to facilitate people's expressions of creativity at each level. People on the doing level need to be leaded, on the adapting level need to be guided, on the making level need to be provided scaffolds and on the creating level need to be offered a clean slate. Designers will be necessary to aid the users through the design process by design thinking (Sanders & Stappers, 2008).

3. METHODOLOGY

3.1 DESIGN PROCESS

This research is a combination of design-based research and exploratory research. Such a design process, as shown in figure 5, starts with the fuzzy front end, referring to the chaotic nature of this phase (Sanders & Stappers, 2008). The status of the deliverable is still unknown in this phase and the goal of this phase is to determine what is to be designed. Subsequently, design criteria are formulated, ideas are formed into concepts and prototypes are improved by an iterative process, resulting in the product.

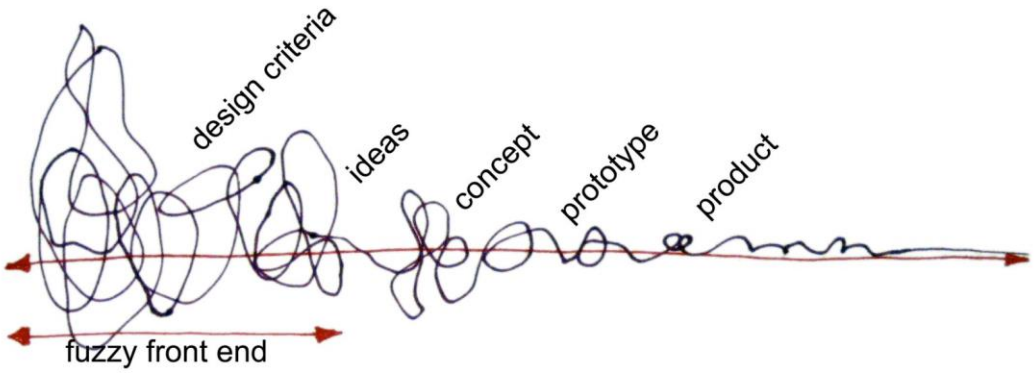


FIGURE 5: PROCESS OF CO-DESIGN. GOING TOWARD THE FINAL PRODUCT, IDEAS BECOME MORE CONCRETE (SANDERS & STAPPERS, 2008).

The process of this research was split up in four phases, according to the British design-based research method (UK Design Council, 2007). However, the shape of the double diamond used in design-based research was adapted, due to the exploratory nature of this research (figure 6).

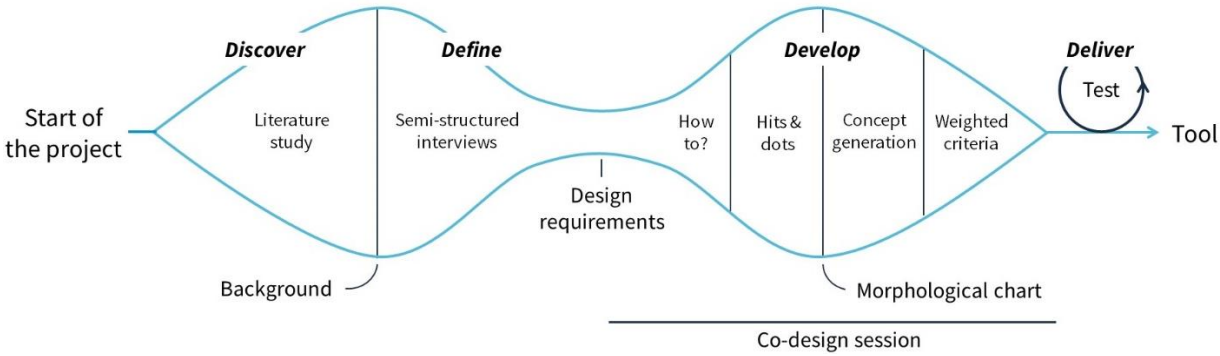


FIGURE 6: THE PROCESS OF THE DESIGN PROJECT, STARTING WITH A DISCOVERING PHASE AND A DEFINING PHASE, FOLLOWED BY A DEVELOPING PHASE AND CLOSING WITH A DELIVERY PHASE.

In the discovery phase literature research was done and interviews were conducted. The goal was to broaden the knowledge on the topic, so this was a diverging step. This resulted in the answer on the first three research questions. Afterwards, design criteria were being defined from the interview and literature research in the defining phase. Design requirements were grouped and narrowed down in this converging step. Next, a morphological chart was created by generating solutions for each design requirement by a co-design process in the developing phase. In the design-based research method, a scenario phase would follow after filling in the morphological chart. However, because of time limitations of the participants, this step was skipped and the concept generation phase was initiated. Several concepts were formed in this diverging step. The concepts were weighted and one was chosen

and worked out in the delivery phase (converging phase). This could also be done using a second morphological chart. However, the generated concepts were already worked out partially by the participants and using the help of the designer, this was not necessary. Afterwards, an iteration was done by testing the tool with the target group, resulting in the final product.

Combining the adapted design-based research method and co-design to create a tool for Responsible Research and Innovation, is a unique new methodology. In this way RRI is being operationalized. A one page summary of this self-developed methodology can be found in appendix 17.

3.2 LITERATURE STUDY

To provide a background on RRI, reflexivity and co-design for sub-questions 1, 2 and 4, and finding current methods or tools for increasing reflexivity to answer sub-question 3, a literature study was performed.

The literature study was performed in a narrative manner. The search terms were based on the aim of this research and the research questions (appendix 1). Google Scholar was used as a search engine. Using the literature found with the specific search terms, additional literature was found using the snowball method, in which articles were found by using the reference list of other articles (appendix 1). Besides, theses of other students, graduating on similar subjects or with similar methods were used to find relevant literature (Stenfert, 2017; Stolk et al., 2016; Wesselman, 2017), and reports of students working on the same subject were used (Keutel & van Hattum, 2017; Smeets et al., 2017). Also reports concerning NUCLEUS were used (Böger et al., 2017; Flipse & van der Sanden, 2016; Gerber, 2014). Furthermore, literature via my supervisor Steven Flipse was obtained (Engineering and physical sciences research council, 2018; Flipse et al., 2013b; Penders et al., 2009; UK Design Council, 2007; van der Meij et al., 2017) or via previous courses (Wenger, 2000). In this way, all general and most cited papers covering RRI, reflexivity, midstream modulation and co-design are thought to be found.

After writing the background chapter, all criteria for reflexivity named in this literature were taken into account as design criteria for the tool. Since all topics considering the research question were covered in the background section, these were also covered in the design criteria of reflexivity for the tool.

3.3 SEMI-STRUCTURED INTERVIEWS

To study the view of fundamental researchers on RRI and reflexivity to answer sub-questions 1 and 2, four semi-structured interviews were conducted. Besides, their view on creating a tool or method for stimulating reflexivity of fundamental researchers was asked. Semi-structured interviews were chosen to allow the interviewees to bring in new ideas on a tool or method, but all participants got the same basic questions. In this way, the interviewees could openly think about criteria for the tool. Using these findings, design criteria were set-up for the tool or method.

3.3.1 Sample

Four PhD students of different nationalities, each from a different research group of the department of bionanoscience within the faculty of applied sciences of the TU Delft, were interviewed. The participants were chosen up front as they should conduct fundamental research. To get a broad

overview of reflexivity during the whole period of a PhD, all participants picked were third or fourth years PhD students. Because of the network gained from my master thesis of Life Science and Technology, I knew all participants personally or vaguely. Therefore, the chosen participants all did not hesitate to participate.

3.3.2 Procedure

The PhD students were interviewed based on a semi-structured interview protocol with topics to discuss Responsible Research and Innovation, reflexivity and a tool or method to stimulate reflexivity (appendix 2). Interviews were performed face-to-face in meeting rooms at the department of bionanoscience. Before introducing RRI to the participant, they were asked if they had an idea of what RRI was. In this way, they could give an unbiased answer. After this first question the principle of RRI was explained, including the four dimensions. Questions on RRI and these four dimensions were asked. Subsequently, the principle of reflexivity was explained again and I mentioned I would focus on that topic and questions on reflexivity were asked. Afterwards, I explained I wanted to design a tool or method to stimulate reflexivity and used the STIR method as an example of a method to increase reflexivity levels. Questions concerning a tool were asked, to come up with design criteria.

3.3.3 Data processing

The interviews were recorded and partially transcribed (appendix 3). Open coding in NVivo was conducted to search for design criteria for a reflexivity tool or method given by the participants. This was done by reading the transcripts and when a criteria was named, this criteria was indicated as a node. The criteria from the text was indicated as a quote. The following codes were applied: active; concrete; feedback; first year's PhD student; for free; group effort; involve PIs; involve stakeholders; occasion; pressure to use; super-users; taking a step back; visual. The codes are presented in the form of a code tree (appendix 4) and the quotes belonging to the codes are presented in a table (appendix 5).

Besides, information on the view of the participants on RRI and reflexivity was extracted from the first part of the interviews.

3.4 CO-DESIGN PROCESS

To create a tool to stimulate reflexivity, a co-design session was organised. In this way, end-users are involved in the process. Besides, it is studied how a co-design method would help in creating a tool for reflexivity (research question 4).

3.4.1 Sample

In this co-design session, the participants from the semi-structured interviews were invited, since these participants were already informed about this research and wanted to participate once more. However, only one expert (fundamental natural scientist) attended the session. Also, a graduated industrial designer was invited who was familiar with such creative sessions. Besides, the author of this thesis was guiding the session and participating. After this session, the morphological chart was shown to two more PhD students, who also took part in the interviews, to come up with more concepts. This was done to obtain a bigger variety of ideas for concepts. Because the fundamental natural scientists was a 'doing type' (Sanders & Stappers, 2008), a leading and guiding co-design process was carried out.

3.4.2 Procedure

The goal of this session was to come up with a tool stimulating reflexivity, keeping the design criteria in mind. Before starting with this creative session a short game, called 'pinkelen', was being played as an ice-breaker. The session was build up by four phases. The design criteria were the starting point of this session. The "How to?" and "Hits & Dots" phases resulted in the morphological chart. Afterwards the concept formulation and the weighted criteria phase resulted in the final concept. The complete protocol of the co-design session can be found in appendix 6 and an overview of the process is shown in figure 6.

The first phase was the 'How to?'-phase. In this phase the participants were asked to answer sixteen 'How to?' (H2)-questions. Each question was printed on an A3 form. Every participant got one form in front of him/her and had two minutes to write down ideas on sticky notes and stick them to the A3 form. After the two minutes the forms were switched and the same was done for a new H2-question. This was done for all sixteen forms, so in the end everyone came up with ideas for every H2-question.

After this step, the 'Hits & Dots' phase started. In this phase, a selection was being made of the solutions generated in the 'How to?'-phase. Per 'How to?' form everyone could distribute three sticky coloured dots: a green one, a blue one and a yellow one. The green dot should be stuck on the favourite solution, the blue one on the most innovative solution and the yellow one on the most feasible solution. All post-its with stickers on them were gathered and placed on the morphological chart. This resulted in a complete morphological chart.

This was followed by a phase where concepts were generated. Using the ideas on the morphological chart (considering at least three), concepts were made up. This was filled out on a form including the name of the concept, a general description with what it is? Who is involved and when should it be used.

After the co-design session, the morphological chart was shown to two more PhD students, who also took part in the interviews. Using the solutions from the morphological chart, more concepts were generated.

These concepts had to be scored in the last phase using weighted criteria. These five criteria were defined in the introduction section: The tool should stimulate reflexivity of fundamental scientists; The tool should be considered as useful by the scientists; The tool should be implemented at the BN department of the TU Delft; Creating the tool should be feasible within the available time of a master thesis project; Creating the tool should be feasible within the financial means. In the co-design session the weights were defined per criteria. There were 100 points to divide on the five criteria.

The author of the thesis scored all concepts on the five criteria (on a scale from 1-5). Using these scores and the weights per criteria a final score was formulated per concept. The best four concepts were discussed with one of the supervisors and the most feasible concept was chosen.

3.4.3 Data processing

During the session pictures were made of the 'How to?' forms (appendix 7), the morphological chart (figure 8), the weighted criteria form and the concept forms (appendix 8) to store them.

To work out the concept, two industrial design graduates helped. Separately, they saw the design and manual and checked it on understandability and visual design. These were the first two iterations on the design.

3.5 TESTING OF TOOL

To be able to give answer to the research question "To what extent can reflexivity amongst PhD students in fundamental research within the TU Delft be stimulated with a simple and sustainable tool or method?", the tool should be tested and experiences using the tool should be gathered. Therefore, a test and a group interview were performed, being the third iteration.

3.5.1 Sample

Since the purpose was to introduce the tool to first year's PhD students, the test group consists of two first year's PhD students, one second years PhD student and one third years PhD student. The four PhD students have three different nationalities and work in three different research groups (Hyun Youk, Liedewij Laan, Christophe Danelon) of the department of bionanoscience within the faculty of applied sciences of the TU Delft. The participants were chosen up front as they should conduct fundamental research.

3.5.2 Procedure

First of all, a short introduction on the session and the tool was given. The previous steps of this thesis project were discussed and the mirror tool was introduced. No further information on the method was provided, to make sure the participants were unbiased from the start.

The participants were all given a folder including the 'mirror forms', an example form and the manual. They got 30 minutes to read the manual and fill in two or three 'mirror forms' for three different projects. At least one of the projects had to be a big project and at least one a small project or experiment. The protocol of the test session can be found in appendix 12.

Afterwards, the PhD students were interviewed based on a semi-structured interview guide (appendix 13) to review the tool. The group interview was performed in the same meeting room at the department of bionanoscience. First of all, they were asked to give their global impression on the tool by asking them about what they liked and did not like. Afterwards, the effect on reflexivity by using this tool was discussed using the criteria for reflexivity. Then, the use (manual) was discussed. Furthermore, when, why, with who and how often the tool should be used was discussed. Lastly, suggestions for improvement were asked. During the interview, all participants were equally involved.

3.5.3 Data processing

The group interview was recorded and transcribed (appendix 14). Improvements for the tool were used for the final design. Besides, the test results were important to visualise the future use of the tool.

3.6 REVIEWING TOOL WITH A PRINCIPLE INVESTIGATOR

To be able to give answer to the research question "To what extent can reflexivity amongst PhD students in fundamental research within the TU Delft be stimulated with a simple and sustainable tool

or method?", the tool was evaluated with a principle investigator (PI) of the TU Delft. In this meeting the tool, implementation of the tool and future use of the tool was discussed.

3.6.1 Sample

Since one of the requirements of the tool is that it should be implemented at the BN department of the TU Delft, a PI of the BN department of the TU Delft was interviewed.

3.6.2 Procedure

The PI was interviewed based on a semi-structured interview guide (appendix 15). The interview was performed in the office of the PI at the department of bionanoscience. First, the PI was asked about the opinion on the tool, afterwards about the implementation of the tool and lastly about the future of the tool.

3.6.3 Data processing

The interview was recorded and transcribed (appendix 16). The opinion on the tool was extracted from the interview as well as suggestions on implementation and future use of the tool. Improvements for the tool were used for the final design.

4. RESULTS

4.1 DISCOVER: VIEW OF FUNDAMENTAL RESEARCHERS ON RRI AND REFLEXIVITY

To figure out to what extent reflexivity is a suitable method of RRI for fundamental researchers (research question 1) and to identify the motives of fundamental scientists for being reflexive or not (research question 2), interviews were performed. First the interviewees were asked whether they knew the term RRI. Then RRI, including the four dimensions, was explained to the participants and they were asked which dimension suited them best. Afterwards, reflexivity was explained and their motives for being reflexive were identified.

4.1.1 Researchers view on RRI

Even though, over time the term Responsible Research and Innovation has become more commonly known, none of the four interviewed PhD students knew the term. When asking if they knew what RRI meant, they answered: "I think I have a vague idea, but I might be completely wrong" and "I don't really know. Of course, the name is quite descriptive." Giving them the description of RRI, they were familiar with the content: "I mean of course I know these things, I just didn't know the term."

The view of the participants on RRI of this research ranged from very positive ("This is kind of an idealist situation") to negative ("I am a bit disconnected to all this"). The negative reaction was due to the field of research. This participant thinks fundamental research is not socially relevant ("I have the feeling that it is not that important for my research. Because I think my research is not that world changing"), similarly to the results of Böger et al (2017) and Smeets et al (2017).

Also, the participants were asked whether they felt connected with the four dimensions of responsible research and innovation, defined by Owen (2013): anticipation, reflexivity, inclusion and responsiveness. The results on this question were inconclusive. One of the participants said: "I am a bit disconnected to all this", while another participant said: "A little bit of everything". However, most of them mentioned no connection was found with anticipation: "… anticipation is very hard for fundamental research. We tend to think about it a bit, because we have to sell the project. But in practice you have no idea where it might go."

4.1.2 Reflexivity of fundamental researchers

Being a bit negative on anticipation and RRI in general, all four interviewees recognized the importance of being reflexive: "The more we have this, the better science we are going to do, the better scientists we are going to have." The participants gave four different reasons for being reflexive. First of all, reflexivity is important for keeping motivation: "a lot of the times if you don't start thinking of the bigger picture (…) then you can really lose motivation because things don't work for months." Secondly, you have a certain responsibility using the tax money: "I feel responsible because I am also spending tax payer money." Thirdly, three interviewees mentioned it is necessary to be reflexive to get good results for articles: "Because you want to create a nice story, that things are connected. To get a story, you need to think about it first and try to plan it." Lastly, it was mentioned reflexivity is important, as it is more time efficient: "You just become way more effective if you think about what you are doing, before you do it."

Besides, they all said training would be helpful to become more reflexive. "I think for PhD students it might be useful, cause we a lot of the times just tend to get lost in the details and really get stressed

out and lose the bigger picture" and "I think it would be an interesting topic for me and I think it is necessary."

Remarkably, the scientists were more interested in micro-ethics than macro-ethics. "I think reflexivity, that's the thing most scientists will do a lot, the whole time. On a small skill we have to think about our experiments every day and a bit further we have to think about papers, so we have to plan this. But I think it is very paper driven (…) and not necessarily how can this impact society." This can be explained by them being not connected to the term anticipation and therefore considering the future impact with its social, ethical and economical aspects too far away from what they are doing.

4.2 DEFINE: DESIGN CRITERIA

Besides sharing their view on RRI and reflexivity, the interviewees were asked to share their ideas on creating a tool for reflexivity. From these findings, design criteria were formulated.

4.2.1 Forming design criteria from interviews

Design criteria of the tool are filtered from the interviews. From the interviews thirteen design criteria were formulated. The boundaries are indicated by the research questions and limitations of the study, being 'the tool should stimulate reflexivity of fundamental scientists', 'the tool should be considered as useful by the scientists', 'the tool should be implemented at het BN department of the TU Delft', 'creating the tool should be feasible within the available time of a master thesis project' and 'creating the tool should be feasible within the financial means'. The design criteria are discussed in the order of frequency of mentioning. A summary of the design criteria can be found in table 1 and quotes concerning each design criteria can be found in appendix 5.

Four design criteria were mentioned by all participants. First of all they mentioned the tool should be applied to first year's students. For example the participants said: "I think in the beginning of your PhD it is really useful" and "I already noticed now of myself, that I do it [reflecting] now more than before, when I just started." Secondly, all of them mentioned using the tool should be a group effort, saying: "I think interaction with other people is important" and "How I learned it so far, is indeed by talking to others. That would be an ideal way, especially within your research team." Furthermore, all of them mentioned principle investigators should be involved: "Especially if you would have a PI that does something like this, it would be a stronger statement. Because they have already proven themselves as a scientist" and "Not PhDs only, but also PIs trained on how to communicate those tools." Lastly, all participants mentioned the tool should be used whenever you want to: "The start of the project is just the best example where it could be useful. But it would be good to come back also in interval" and "It depends a bit on the goal, if you want to reflect more on specific experiments then I would say daily or whenever you do it."

All but one participant mentioned two other design criteria. Firstly, they mentioned the tool should be something to do: "something to do means that you have to think about it" and "It should be something that reminds you automatically, like an email or something." Secondly, three of the participants mentioned, without asking them directly, that tool needs to be concrete, not vague: "It should be as straight forward as possible" and "It has to be down to earth, down to exactly what people are doing."

Two of the participants mentioned five other design criteria. First of all, they mentioned that the tool should be applied at the start of the project: “When things don’t work or when you just finish or start a project” and “For example, I started this new project, it might help to not get lost.” Secondly, they mentioned that the tool should give feedback to the user: “I think [working with] colleagues would be good. If it is just a computer program, the feedback is missing.” Furthermore, two of the participants said that there should be pressure to use the tool: “I think this will be hard to make people use it if there is no pressure” and “Then you have to make it a way like a Kavli day, that people have to go there.” Besides, two participants said that the tool should be supported by role models: “And I think the most important thing is to have people trained on that and would understand how important is that. Not PhDs only, but also PIs should be trained on how to communicate those tools” and “They might be better models. There are some PIs which are very popular.” Lastly, two participants mentioned the tool should take you a step back to view the bigger picture: “If it does not work according to your hypothesis and you feel sad, but then you know you need to take a step back” and “That you are always reminded of this is the big pictures or this is the goal.”

Two criteria were mentioned by one of the participants. First of all, it was mentioned that the tool should be visual, since then “you can always go back to it”. Secondly, using the tool should involve stakeholders: “Maybe you need to have a very broad audience, first with the most closely related group of people, then you move to general scientists and then you move to general public, people who are not being a scientist.”

TABLE 1: DESIGN CRITERIA FOR A TOOL STIMULATING REFLEXIVITY, EXTRACTED FROM THE SEMI-STRUCTURED INTERVIEWS.

Nº	**Design criteria interviews**	**Mentioned by (number of persons)**
1	The tool should be applied to first year’s PhD students	4
2	Using the tool should be a group effort	4
3	Principle investigators should be involved when using the tool	4
4	The tool should be applied whenever needed	4
5	The tool should be concrete, not vague	3
6	The tool should be something to do (something active)	3
7	The tool should be applied at the start of a project	2
8	The tool should give feedback	2
9	There should be pressure to use the tool	2
10	The tool should be supported by role models (super-users)	2
11	The tool should take you a step back to view the bigger picture	2
12	The tool should be visual	1
13	Using the tool should involve stakeholders	1

4.2.2 Forming design criteria from literature

In table 2 the criteria for reflexivity found in literature are listed. Descriptions of these criteria can be found in various paragraphs of the background chapter. First of all, the criteria can be found in paragraph “2.1.5 Quality criteria RRI”. However, only the criteria applying to reflexivity in this paragraph are used as design criteria (criteria 14 and 15). Secondly, design criteria are gathered from paragraph “2.2.3 Criteria of reflective thinking”. All criteria named in this paragraph are used as design criteria (criteria 16-25). Lastly, criteria are picked from the paragraph “2.3 Current tools for increasing reflexivity”. All criteria concerning reflexivity were added to the list of design criteria from literature

(criteria 26-29). The other paragraphs in the background section did not mention any criteria for reflexivity.

TABLE 2: CRITERIA FOR REFLEXIVITY FROM LITERATURE INCLUDING THE CORRESPONDING REFERENCE.

Nº	**Criterion for reflexivity**	**Reference**
14	Analysis of the background, current situation and context of the research or innovation.	(Kupper et al., 2015)
15	Facilitating deliberation on values perceptions, needs, interests, choices, and definition of the problem at issue in the practice.	(Kupper et al., 2015)
16	The need of experimentation space including openness, elimination of initial judgement and freedom to make errors, voluntariness, time abundance and flexibility in the process structure and order.	(van der Meij et al., 2017)
17	Focus is being essential for playfulness, meaning expectations throughout the project should be made clear.	(van der Meij et al., 2017)
18	Stimulating guidance is necessary. This includes personal attention, rewards and feedback.	(van der Meij et al., 2017)
19	Reflection is a meaning-making process.	(Rodgers, 2002)
20	Reflection is a systematic rigorous, disciplined way of thinking.	(Rodgers, 2002)
21	Reflection needs to occur in interaction with others.	(Rodgers, 2002)
22	Reflection requires attitudes that value the personal and intellectual growth of oneself and others.	(Rodgers, 2002)
23	The interventions should be done in the R&D phase	(Flipse et al., 2013b)
24	The integration of social and ethical aspects need to be done during decision making processes.	(Flipse et al., 2013b)
25	Support or reward of the organisation is necessary to include social and ethical aspects in the work of the researchers.	(Flipse et al., 2013b)
26	Reflexivity should help considering: “What are you doing? Why? Alternatives? Outcomes?”	(Fisher, 2007)
27	STIR should be carried out voluntary (for the researchers), open-ended, structured and systematic	(Stolk et al., 2016)
28	The tool should help considering socio-ethical and socio-economic aspects.	(Flipse & Bayram-Jacobs, 2016)
29	Providing time, space and context stimulates reflexivity.	(Nadin & Cassell, 2006)

4.2.3 Grouping design criteria

Since some of the criteria found using the interviews and in the literature were comparable, these criteria were merged into one criterion. This resulted in a list of sixteen design criteria, shown in table 3. In the second column is shown which criteria from table 1 and 2 are merged.

Besides, two of the criteria are left out, as these are starting points of the research, described in the introduction. These are criteria 23 and 24, being criteria for midstream modulation.

TABLE 3: MERGED LIST OF DESIGN CRITERIA FOR A TOOL STIMULATING REFLEXIVITY. SIMILAR CRITERIA FROM THE INTERVIEWS AND LITERATURE ARE MERGED INTO ONE CRITERION. IN THE SECOND COLUMN THE (MERGED) CRITERIA FROM TABLE 1 AND 2 ARE INDICATED.

	Nº	**Design criteria interviews**
A	1	The tool should be applied to first year's PhD students
B	2 & 21	Using the tool should be a group effort
C	3	Principle investigators should be involved when using the tool
D	4 & 7	The tool should be applied at .. (which occasions)
E	5	The tool should be something to do (something active)
F	6 & 17	The tool should be concrete, expectations should be made clear
G	8 & 18	The tool should give feedback
H	9 & 25	There should be pressure to use the tool (by the organisation)
I	10	The tool should be supported by role models (super-users)
J	11, 19 & 29	The tool should take you a step back to view the bigger picture
K	12	The tool should be visual
L	13	Using the tool should involve stakeholders
M	26 & 14	The tool should help considering: "What are you doing? Why? Alternatives? Outcomes?"
N	16, 22, 15 & 27	Using the tool experimentation space is needed - openness, elimination of judgement.
O	28	The tool should help taking socio-ethical and socio-economic aspects into account.
P	20	The tool should facilitate a systematic and disciplined way of thinking.

4.3 DEVELOP: A REFLEXIVITY TOOL

Using the design criteria, the goal is to develop a tool for stimulating reflexivity of fundamental scientists. This was done in a co-design session with one previous participant of the interviews and with a graduated industrial designer. This session consisted of three parts: subsequently, answering 'how to?' questions, the selection of the best solutions and generating concepts. Two other participants of the interviews individually helped with concept generation to increase the amount and variety of concepts.

4.3.1 "How to?" (H2) questions

To find solutions for each of the design criteria, these were rewritten to the following H2-questions:

- How to make a tool active (something to do)?
- How to apply the tool to first year's PhD students?
- How to take social-ethical and social-economic aspects into account?
- How to make a concrete, not vague, tool?
- How to create experimentation space (openness, elimination of initial judgement and freedom to make errors, voluntariness, time abundance and flexibility in the process structure and order)?
- How to get feedback?
- How to make the process a group effort?
- How to involve principle investigators?
- How to apply the tool (at which occasions)?
- How to apply pressure on people to use tool?
- How to support the tool by role models?
- How to involve stakeholders?
- How to take a step back to view the bigger picture of the research?
- How to facilitate a systematic and disciplined way of thinking?
- How to make a tool visual?
- How to include considering: 'what are you doing? why are you doing that? what are the alternatives? and what are the outcomes?

Per H2-question, each participant had two minutes to think of solutions. These solutions were written on sticky notes and stuck on an A3 form with the corresponding question (figure 7). This resulted in eight to fourteen solutions per H2-question (appendix 7).

FIGURE 7: THREE EXAMPLES OF 'HOW TO? '-QUESTIONS INCLUDING SOLUTIONS ON POST-ITS FORMULATED DURING THE CO-DESIGN SESSION.

4.3.2 Selecting solutions

To select the best solutions, all participants choose the two most innovative (blue dot on a sticky note), two most feasible (yellow dot on a sticky note) and two favourite (red dot on a sticky note) solutions from each H2-question. All sticky notes with coloured dots on them were gathered and placed on the morphological chart (figure 8).

FIGURE 8: MORPHOLOGICAL CHART INCLUDING THE MOST INNOVATIVE, MOST FEASIBLE AND FAVOURITE SOLUTIONS ON EACH DESIGN CRITERIA. SEE FIGURE 10 FOR THE FILLED-IN CHART.

4.3.3 Forming concepts

To come up with concepts of a tool, method or activity, the solutions on the morphological chart could be combined. For making the concepts, not every criterion had to be taken into account, but at least multiple. First this was done during the co-design session by the expert, the designer and the author of this thesis. Afterwards, this was done in two sessions with two other participants together with the author of this thesis, to get a large amount and variety of concepts. In this session, the filled-in morphological chart was shown to the participant, all solutions on the chart were discussed and using these solutions, concepts were generated by the participant. After the co-design session and the concept generation sessions with the two other participants, sixteen concepts were generated (appendix 8).

The participants were instructed to use several solutions of the morphological chart to come up with concepts. However, during the concept generation it was not tracked which solutions were used for the various concepts. Therefore, afterwards the concepts were validated by the author of this thesis using the morphological chart by connecting solutions resulting in the concept. In this way, it was shown the solutions on the morphological chart corresponded to the concepts. Three examples are given for the connected solutions (figure 9). The three examples are the ‘overview form’ (orange), the ‘reflexivity association’ (blue) and the ‘diary’ (yellow).

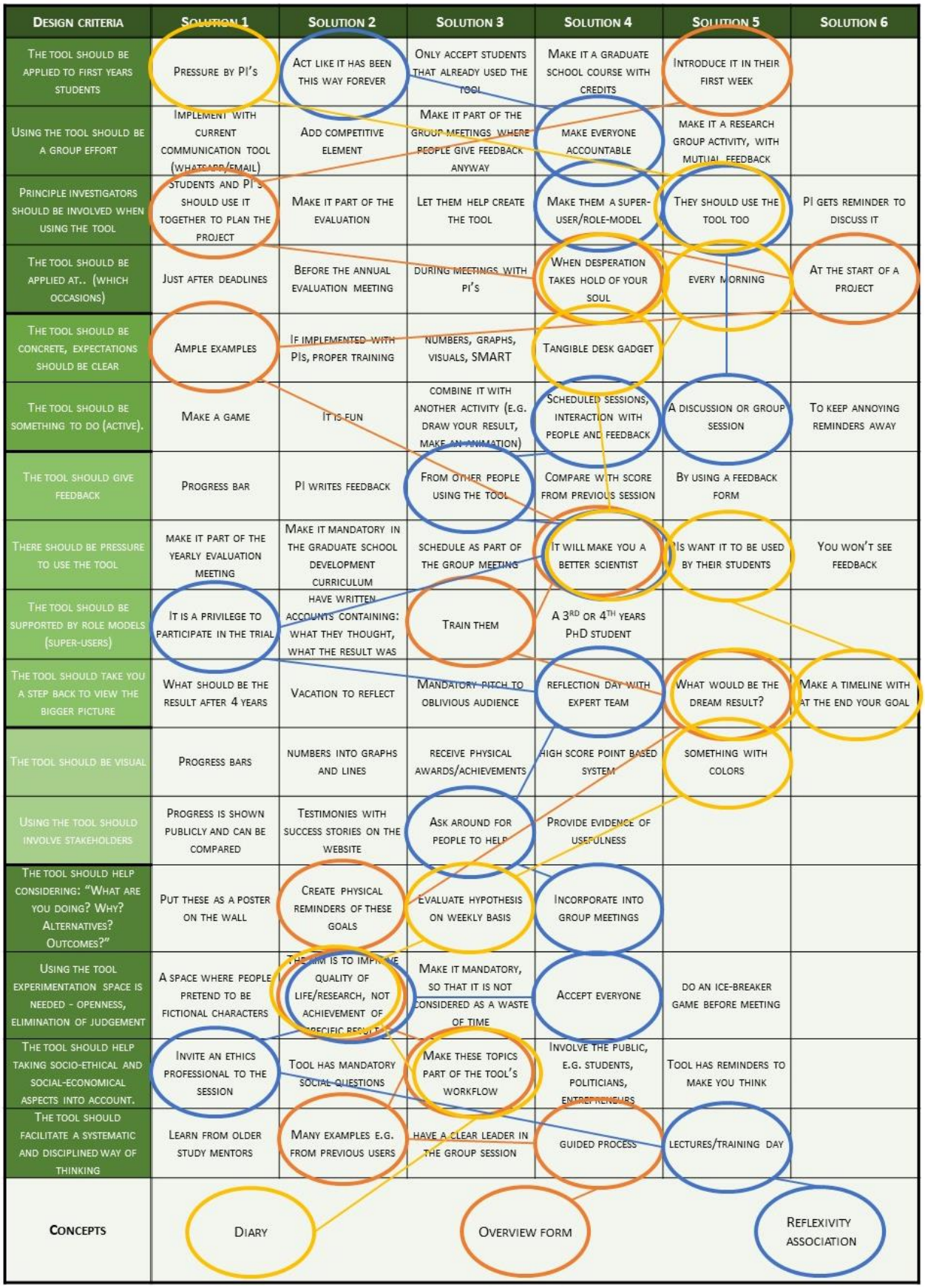


Figure 9: Morphological chart including scenarios for the overview form (orange), the reflexivity association (blue) and diary (yellow)

The ‘overview form’ is a form to look at the bigger picture of a project. This is done by answering the questions ‘What?’, ‘Why?’, ‘Alternatives?’ and ‘Outcomes?’ about the project. Therefore, this method resembles the STIR method (Stolk et al., 2016), but is a more simple alternative. It can be used at any desirable stage in the project, but especially at the start of a project or when struggling with a project.

The ‘reflexivity association’ is an open group of people that organizes talks, group meetings and workshops to stimulate reflexivity. In this association the group process is very important, giving each other feedback and involving PI’s and stakeholders.

The ‘diary’ is a premade booklet including questions stimulating reflexivity but also including blank space to keep track of what you are doing, like the research diary described in the background section (Nadin & Cassell, 2006). This booklet can be used daily or when struggling with a project and it should be used individually or with the PI.

4.3.4 Observations co-design process

To study how a co-design method would help in creating a tool for reflexivity, observations were done during the co-design session. The co-design process was carried out together with one previous participant of the interviews and with a designer. This resulted in a combination of different perspectives on the tool: the creative perspective of the designer, the expertise perspective of the fundamental natural researcher and the expertise perspective of the social scientist.

During the process of coming up with solutions to the H2-questions, these different perspectives were clearly visible. For example when answering the question “How to make the tool concrete, not vague?”, the designer answered “tangible desk gadget”, the expert answered “If implemented with PI’s, proper training” and the social scientist answered “Use super-users or ambassadors”. In this way you can see the designer had a broad creative view, the expert had a view applicable to the BN department and the social scientists used social theories.

Reading each other’s answers to the H2-questions and picking the most feasible, favourite and most innovative solutions we could indeed clearly see the differences in the answers. Besides, when picking the most favourite solutions most often the solution of the expert was chosen, when selecting the most feasible solution, mostly the solution of the social scientist was chosen and when choosing the most innovative solution, most often the solution of the designer was picked (table 4). This resulted in a variety of solutions on the morphological chart.

TABLE 4: COUNTS ON FAVOURITE, MOST FEASIBLE AND MOST INNOVATIVE SOLUTIONS ON THE H2-QUESTIONS PER PARTICIPANT.

	Designer (orange)	**Expert (yellow)**	**Social scientist (green)**
Favourite (white)	14	26	8
Most feasible (red)	15	15	18
Most innovative (blue)	29	12	7

The process of generating concepts was a more individual process. However, due to the large variety of the solutions on the morphological chart, the view of all participants was broadened. Therefore, feasible, favourite and innovative solutions could be combined to the best solutions.

4.3.5 Choosing concepts

The best concept was selected by weighing all concepts on each main criterion (described in the introduction). The weight of the criteria was determined by the participants of the co-design session. One hundred points were distributed over the five criteria. Stimulating reflexivity was the most important criterion with thirty-five points. Feasibility (time) got twenty-five points, usefulness twenty points, feasibility (costs) fifteen points and implementation at BN got five points. The concepts were scored on these criteria on a scale from 1 to 5 by the author of this thesis. This was not done during the co-design session since the time was limited. All scores were discussed with Steven Flipse, the first supervisor of this thesis project. Using the weights and the scores an end score for each concept was calculated.

As can be seen from table 5, the "Overview form" had the highest end score. This was largely due to the high score on reflexivity and feasibility (in time and costs). The "Exercise form" and the "Questionnaire with colleague" were runner-up, scoring lower on all criteria except for stimulating reflexivity for "Exercise form" and on feasibility in time and implementation at BN for "Questionnaire with colleague".

TABLE 5: CONCEPTS SCORED ON EACH WEIGHTED CRITERION. THE SCORES RANGED FROM 1 TO 5 AND WERE ASSIGNED BY THE AUTHOR OF THIS THESIS. THE WEIGHTS OF THE CRITERIA WERE DEFINED DURING THE CO-DESIGN SESSION.

	Stimulate reflexivity	***Feasibility (time)***	***Usefulness***	***Feasibility (costs)***	***Implementation at BN***	***End score***
Weight	35	25	20	15	5	
Evaluation form 2.0	3	5	2	5	1	**3,5**
Overview form	5	5	4	5	3	**4,7**
Reflexivity badges	3	4	2	3	1	**3,0**
Outlook buddy	5	2	5	3	3	**3,9**
Dairy	4	5	3	4	3	**4,0**
High score	3	4	4	2	1	**3,2**
Quo vadis+	4	1	1	4	4	**2,7**
Questionnaire to public	3	3	1	4	3	**2,8**
Weekly summary of diary	4	1	4	3	3	**3,1**
Task app	1	4	5	4	3	**3,1**
Project chart	1	5	4	5	3	**3,3**
Reflexivity association	5	1	4	5	1	**3,6**
Exercise form	5	4	4	4	4	**4,4**
Questionnaire with colleague	5	3	5	5	1	**4,3**
Reflexivity course	5	1	4	3	2	**3,4**
Reflexivity app	5	2	5	2	5	**3,8**

These three concepts were worked out and discussed with Steven Flipse. Based on the feasibility (in costs and time) it was decided during this discussion to only work out one of the concepts, the "Overview form". In this way, there was still time within the project to design and test this concept.

4.3.6 Developing design

The "Overview form" was chosen as the best concept based on the criteria. As this name was a bit too general, the concept was renamed to the "Mirror tool" with a "Mirror form". Essentially, with this method you are holding up a mirror to your own activities, commitments and assumptions, keeping in mind your limits of knowledge and framing of the issue.

The mirror tool resembles the STIR method used for midstream modulation. The same questions are asked, like 'What are you doing?', 'Why are you doing it?', 'How else could you do it?' and 'What will this lead to?'. This will help looking at the bigger picture of a project and thinking critically about your own activities and assumptions. This will lead to more thoughtful choices leading to a more ethical and socially desirable situation.

Based on this similarity, a first design was made for the mirror tool and mirror form using aspects of the STIR method. No second morphological chart was used for this step. Instead, the design was formed and discussed with a graphical designer. In this way, multiple forms of such an overview form were discussed, making a morphological chart redundant. Afterwards, the design itself, including colour use and different shades of grey, shapes of the text boxes and font style were discussed. This resulted in the design shown in appendix 9.

Afterwards, it was tested with an industrial designer on the usability. She tried to fill in the mirror form using the manual and the example forms. When doing so, she encountered various problems which were used to improve the design. This resulted in the following changes in the design: adding a field to fill in the date, placing the text boxes below each other instead of in a 'circle', adding guidelines to the manual and separately giving example forms, adding 'How do you fill in the mirror form?' to the manual and using folders to gather the manual, mirror forms and example forms. This resulted in a design (appendix 10), which was used for the test session.

In addition to the four questions named before, also the question 'So What?' is added on the back of the mirror form used for the test session. To become reflexive, this question is unnecessary to answer as reflexivity only concerns awareness. However, to give more purpose to the tool, this question was added. In this way users are able to respond to the changing situation, so not only their thoughts will change, but also their actions. This aligns with the fourth dimensions of responsible research and innovation: responsiveness.

This 'mirror tool' can be applied when starting a project, when struggling with a project or just at a standard moment of the week. The projects described in the 'mirror form' could be as large as an entire PhD project or as small as a single experiment. The 'mirror tool' can be filled in individually, in a group with colleagues, with a supervisor or with a collaborator. The example forms can be used to help to fill in the 'mirror form'. The examples used are from the master thesis of Life Science and Technology of the author of this thesis.

4.4 DELIVER: TESTING A TOOL FOR RRI

To test the effectiveness of the tool and to get answer to the main research question "To what extent can reflexivity amongst PhD students in fundamental research within the TU Delft be stimulated with a simple and sustainable tool or method?", the tool was tested by four PhD students in fundamental research. After using the tool, the participants were interviewed to share their experiences. The transcript of this interview can be found in appendix 14.

4.4.1 Global impression

To study the usefulness of the tool, the participants were requested to give their opinion on the tool, whether they would use the tool themselves and on the questions asked on the form.

Two of the four participants (P2 and P3) considered the tool as useful, especially when you are stuck or if you have projects that you have not thought through yet: "I think also when you are sort of stuck, then this might be a nice structured way to think back" and "In the part where you are still thinking about how should I do it, at that point it would be really good to evaluate." One of the participants did not see it as useful, since this participant did not have any problems at that moment. The other participant was still figuring out what the project was about, as this participant just started with the PhD project, so it might be helpful a little bit later.

However, when the participants were asked whether they would use the form if it is available, the two first year's PhD students (P3 and P4) said they would use it: "Maybe on daily basis no, but if something that I need to reshape the whole project from the beginning, like something from the last year, yes." But the other participants would not use the form: "So then at some point when you have a problem, and you feel like it is hard for me to just figure it out in my mind, you just sit down and you start writing the things down that you would write in here. But you don't need a form." However, they also mentioned the manual was a nice tool to guide through the process: "I think it would be more useful to learn how to do reflexivity. (..) And it [the form] is nice to guide, but basically, with only this [the manual] I could also do the same."

They agreed that the most useful part was visualizing the alternatives, as this could help brainstorming and thinking through the project: "I think that is, well, to really visualize the alternative for yourself. So well, ok, if I would not do it, then actually what would happen? I think that is the useful part of the form." They also saw the added value of the last question 'So what?': "That is in the end what you are doing it for. Not only to reflect but also to take a decision."

However, two of the participants had some trouble writing the opportunity, as they were eager to also write the considerations already. Therefore, these paragraphs need to be separated more. Besides, in the manual it should be stated more clearly that the opportunity should be a problem, as this was not clear to all participants. Also, it should be more clearly indicated that the outcomes should be applied on the alternatives, as this was also not evident to all participants.

4.4.2 How to use the tool

To make improvements to the tool, the participants were asked to comment on the use of the tool. First of all, comments on the target group and when using the tool is most applicable are discussed. Secondly, the time they needed to fill in the tool was reviewed. Furthermore, whether they rather wanted to fill in the form on their own, with their supervisor (PI) or with their colleagues was debated. And lastly, further suggestions or improvements for the tool are described.

The participants noted that being reflexive is necessary throughout the whole PhD project. However, the structure is most useful for first year's students: "I think this can be nice for first year's and third year's students. Maybe for first year's student it might be more likely you have not developed this kind of technique." Also, they considered using the tool was most helpful when you are stuck or when starting with a bigger project. Therefore, this would not be a certain moment in the week or month, but just whenever you need it: "It could be like when you are really stuck and if you are unlucky this happens every month and if you are lucky that happens twice during your PhD."

The participants needed on average 10-15 minutes to fill in the form. However, in the interview afterwards, they mentioned that they had little time and little space to write, making them feel limited. Therefore, they agreed a computer program including this form with unlimited writing space would be preferred.

Involving the PI when filling in the tool is not considered as useful, as it will take a lot of time of the PI. Therefore, it would be better first to fill in the form yourself and afterwards go to the PI to discuss your decisions or actions: "I think you rather do the form and then go to the PI. I think it is also expected if you go to them you already thought through the stuff you want to discuss with them."

Involving colleagues when filling in the tool, when working on the same project, would be useful, according to the participants: "You are doing this in your head all the time. But maybe when you are working in a group, then to explicitly state all these kinds of things might be useful" and "You verbalize your thoughts basically."

In the end, the participants also mentioned improvements to the tool. First of all, one of the participants suggested to add another step at the end to use for looking back at the form at a later stage and analyse what you planned to do, what you did and how it worked out. However, this participant also said he would not use it himself, but it could be useful for other people. Secondly, another participant mentioned that the alternatives could be presented as bullet points, to see how many alternatives you have and what the outcome is per alternative. Lastly, one participant mentioned to leave out the term 'reflexivity', since this term was unknown and difficult to pronounce.

4.4.3 Stimulating reflexivity

To investigate to what extent reflexivity can be stimulated with the mirror tool, the test group was asked whether this tool helped them to become more reflexive. Besides, they were asked to what extent different aspects of reflexivity were present using the mirror tool.

The two senior PhD students mentioned they did not need this form to become more reflexive: "I think I am usually quite reflexive. I do not necessarily need this form to go through all these steps." However, the two first year's student said the form would help them to guide them when reflecting on bigger projects: "Especially in the beginning because you have so many option now, then it is a little bit, you have to reflect on what you want to do. And indeed for the bigger picture that might be good."

Besides they were asked to comment on different aspects on reflexivity. They said they did not take the socio-ethical and socio-economic aspects into account. This was due to two reasons. First of all, they said they did not have space for it. Secondly, the participants considered fundamental science too far away from the end-product: "I think, because it is still quite far away, the socio-economic aspects, I think it is not a big part of the work." Furthermore, they thought this tool really helped facilitating a

systematic and disciplined way of thinking: “By asking the questions in this order, it already gives some kind of structure. Otherwise you may forget steps and get lost in your own thoughts maybe.” Lastly, they felt they had quite some experimentation space. However, they felt limited by the time: “If I have like more time and take it like a task in project development, I will take more time for it.”

4.4.4 Design

To improve the design of the tool, the participants were asked to give their opinion on the design of the manual, the mirror forms and the folders.

The manual was very clear to all participants: “It is clear, not too long. That is great.” However when the participants were asked to fill in the forms, they often made use of the example form to check what to write down. Therefore, it seemed that in the start they did not exactly know what to fill in. However, one of the participants said: “If you have never done it in this way, it [manual and form] helps you to guide you through. Next time you just do the same thing, but then on an empty sheet.”

The participants like the design of the forms. When filling in the mirror forms, one of the participants did not see the back page of the mirror form. Therefore, an arrow indicating that there is more on the back, should be added.

When giving them the folders at the start of the test, they mentioned it seemed very professional. However, they said they would not need the folder to go back to the previous filled in forms: “I guess it is so specific for when you are filling it in. So I guess as soon as you wrote like a list of actions at the back, you start doing that. Even if you do it again a week later, it has changed at least a bit. So then you would have to do it again instead of looking at the form.”

4.4.5 Evaluation with PI

The final design was evaluated with one of the principle investigators (PI) to discuss the future use and possibilities for implementation of the tool at the bionanoscience department of the TU Delft. The transcript of this interview can be found in appendix 16.

The PI mentioned that “anything designed to improve the self-reflection and to structure it is useful” and that he already uses a reflection form, the ‘milestone structure’. This milestone form consists of nine questions: “What is the bigger area of your work? What is the problem? What do you need to solve the problem? What is your main solution? What question(s) are you going to answer? What should we want to be happy with? What is the chain of results that lead to the main result / solution? Did you answer the question? What are hence implications for future work?” These questions actually resemble the questions on the mirror form, but it is more detailed. Therefore, the PI suggested to add more detail to the mirror form. However, the ‘milestone structure’ does not take the alternatives into account, which was, according to the participants of the test, the most useful part of the mirror form.

Also, the PhD student can be pushed more towards thinking about ethical considerations instead of only scientific considerations. Since the test participants only wrote down the scientific considerations, no ethical or social consideration were taken into account. The PI reacted: “It is also nice to think beyond your direct research topics. Because when you talk to people outside the research, they have these questions.” and “But I would make it more explicit here. I would make it less vague and provide more criteria or components to let them think in this direction.”

Besides, the application of the mirror form was discussed. He agreed with using the mirror form when having a problem or at the start of a project, but also suggested to use it when starting to write a manuscript. In this way, the mirror form can be used to structure the information in order to write the introduction of a paper. Also, the role of the PI using the mirror form was discussed. Especially at the start of the project, when a PhD student would fill in the form, then the PI could also fill in the form and then you confront the two.

Systematically implementing the tool throughout the entire department would be difficult, according to the PI. Therefore, top-down implementation would not be a good strategy as PIs will not accept it. The PI gave two possibilities for implementation. First of all, through courses for first year's PhD students in the graduate school: "And then the student can discuss that with the PI." Secondly, give it to the PIs and convince them to use the tool. Then they can decide whether they want to use the tool or not: "I think everyone would be interested in listening to your story and to try to be convinced." Besides, the PI mentioned before the interview that the tool must be scientifically proven to convince the scientific community to use the tool.

4.4.6 Changes to final design

The following changes will be applied to the design based on the test results. First of all, a sign will be added to guide the users to the questions on the back page. Furthermore, in the manual the opportunity will be described more clearly as a problem description. Also the difference between the opportunity and the considerations will be highlighted. Besides, it will be more clearly stated that the outcomes need to be the outcomes of the alternatives. Moreover, in the manual at 'when do you apply the 'mirror tool'?' the 'on daily basis' will be removed.

Also, one change in the design will be made according to a suggestion of the PI. The PI mentioned to add more components to let them think in the direction of ethical considerations instead of only scientific considerations. Therefore, an extra box was added to separate the scientific considerations from the ethical considerations. These changes resulted in a final design of the mirror form, the manual and the example forms, shown on the next pages (figures 10-13) and full version in appendix 11.

The participants also indicated that a digital form would be more useful, not to be limited in space. However, this will not be changed in the final design, as this is not feasible in time during this thesis project. Besides, they mentioned bullet points per alternative would be useful, since then the alternatives are countable and an outcome for each alternative could be given. This is a good addition for a digital form, but for the paper form this is not convenient in terms of writing space. Lastly, the term 'reflexivity' will not be changed in the manual since this phrase cannot easily be replaced by a similar word.

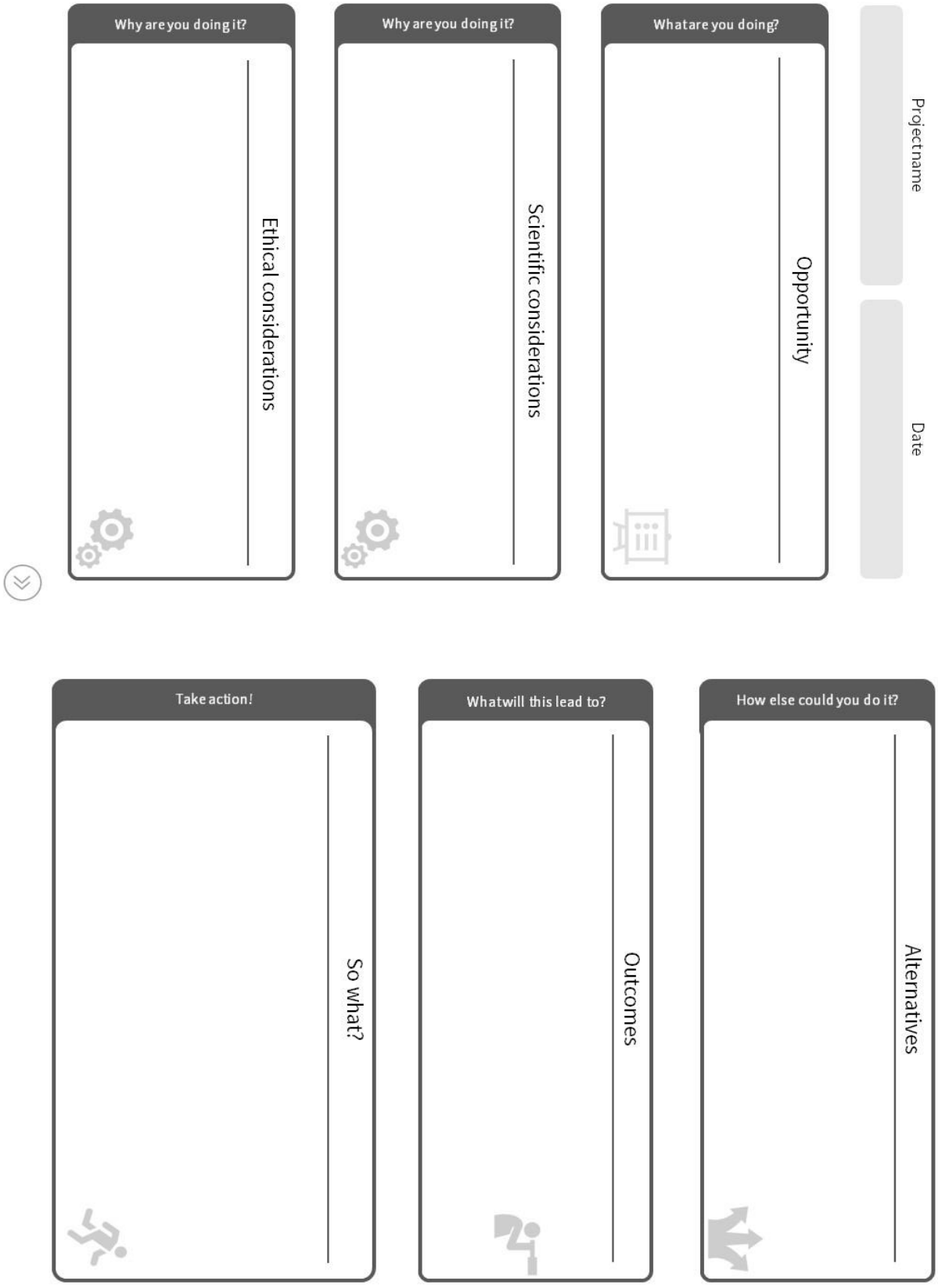


FIGURE 10: THE FINAL DESIGN OF THE FRONT AND BACK PAGE OF THE MIRROR FORM. THIS FORM IS DESIGNED TO STIMULATE REFLEXIVITY OF FUNDAMENTAL SCIENTISTS.

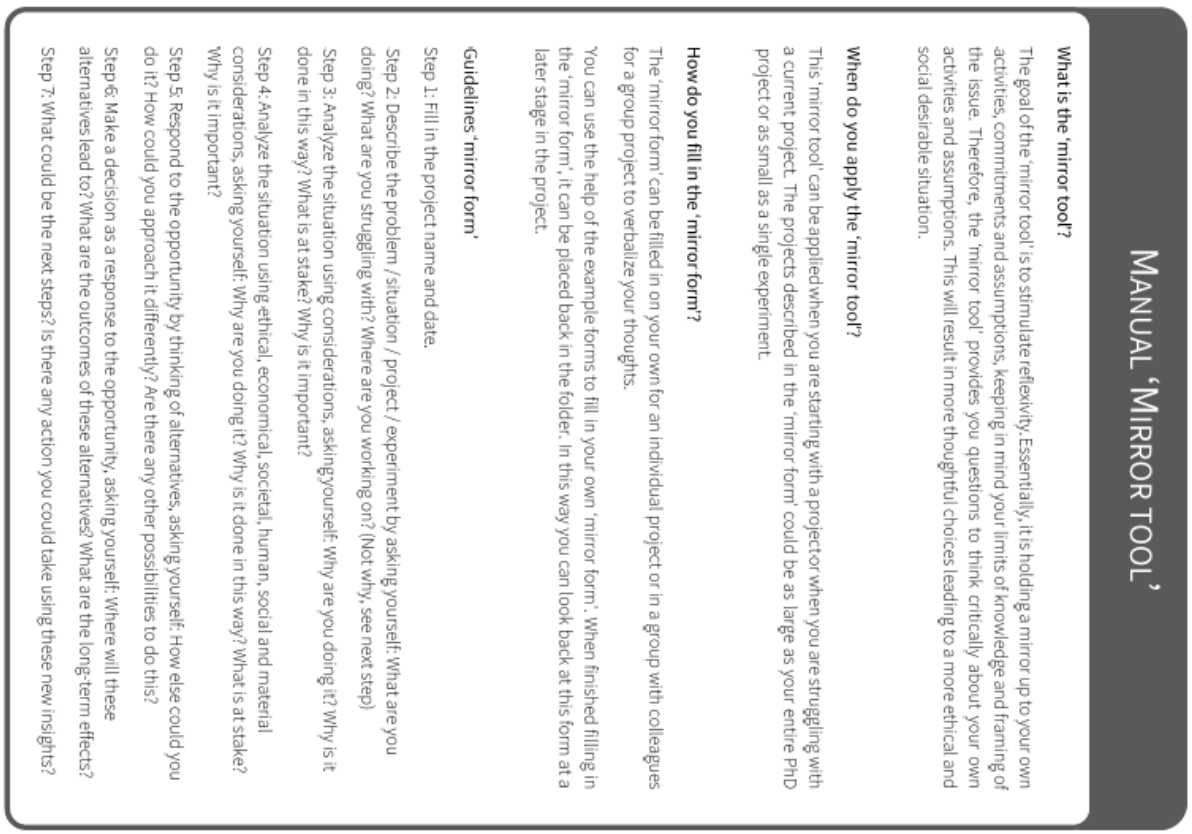


FIGURE 11: THE FINAL DESIGN OF THE MANUAL OF THE MIRROR TOOL TO FILL IN THE MIRROR FORM.

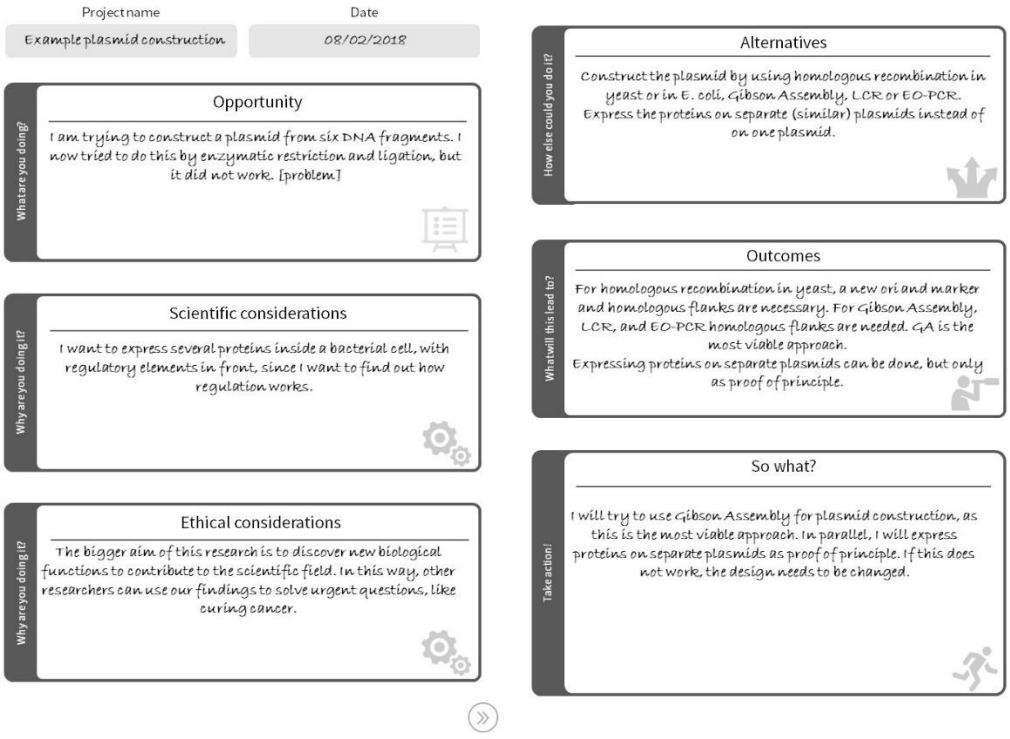


FIGURE 12: THE FINAL DESIGN OF THE EXAMPLE MIRROR FORM 1. THIS EXAMPLE FORM CAN BE USED AS A GUIDE TO FILL IN THE MIRROR FORM.

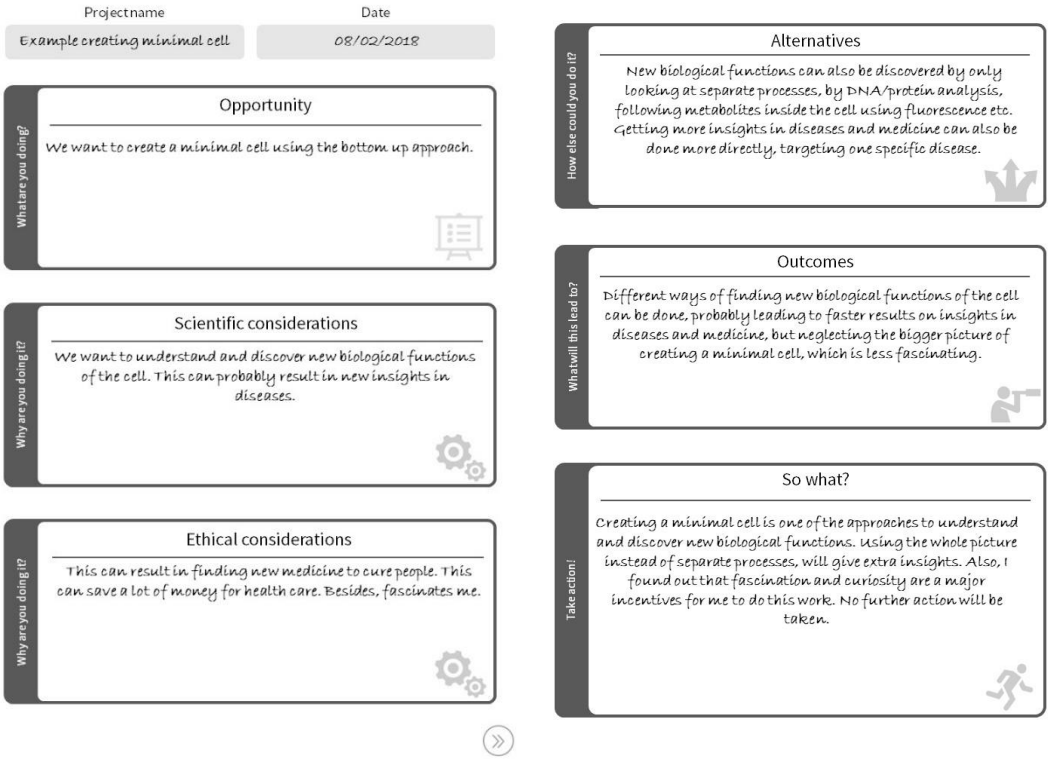


FIGURE 13: THE FINAL DESIGN OF THE EXAMPLE MIRROR FORM 2. THIS EXAMPLE FORM CAN BE USED AS A GUIDE TO FILL IN THE MIRROR FORM.

5. DISCUSSION

In the discussion, the main results will be discussed concerning the tool and the method and limitations of the study will be presented. Moreover, an outlook will be given.

5.1 DISCUSSION OF THE TOOL

In this section, the mirror tool, developed in this study, will be discussed. First of all, the relevance within the NUCLEUS project will be discussed. Then the results of the test will be discussed considering ethics and the target group. Afterwards, the tool will be evaluated on, considering the design criteria and the research question. Besides, the mirror tool will be compared with previous reflexivity stimulating methods. Lastly, the added value of the tool will be discussed.

This research is done within the scope of the Horizon2020 NUCLEUS project. This project aims to bring Responsible Research and Innovation to life in universities and scientific institutions (Gerber, 2014). Instead of building theories on RRI, the goal is to operationalize RRI. This research supported this aim by building a tool to stimulate reflexivity, one of the dimensions of RRI, of fundamental scientist within the TU Delft. Besides this research is the first in which a tool for RRI is made using a co-design approach. In this way, the tool is not only made for scientists, but also with scientists. This was also in line with the NUCLEUS view: ensuring the development of innovative strategies and defining practical recommendations in a co-building mode, ensuring co-responsibility and complementary roles of all partners within the project.

It was noticed that during the test of the mirror tool the participants did not take any socio-ethical or socio-economic consequences of their projects into account. They only described the scientific consequences. This was unexpected as in the manual it is specifically stated that not only scientific considerations should be filled in, but also ethical considerations. They explained that they were first of all limited in space as the boxes of the form were too small. Secondly, they found the socio-ethical and socio-economic consequences too far away from their research. This means they only took micro-ethics into account and not the macro-ethics (Herkert, 2005). However, both kinds of ethics are part of reflexivity, being first and second order reflection (Schuurbiers, 2011). Besides, when asking the principle investigator about micro- and macro-ethics, he mentioned that “It is also nice to think beyond your direct research topics. Because when you talk to people outside the research, they have these questions”. This resulted in the recommendation to add a box to split up the consequences. One box will be for the scientific consequences, as the scientist think this is the most important, and one box will be for the socio-ethical and socio-economic consequences. In this way, the scientists still think it is worth to fill in the mirror form (micro-ethics), but they are also forced to think about the macro-ethics. This is also why fundamental scientists will implement RRI, while they did not do this before.

When starting this project, the target group consisted of (all years) PhD students. However, already in the interviews it was discussed that stimulating reflexivity was most suitable for first year PhD students. Also, when testing the tool, again it was confirmed that the first year’s PhD students appreciated the tool more than the senior PhD students. Therefore, the target group changed from (all years) PhD students to first year’s PhD students. Besides, probably also more mature researcher could be a target group, according to the PI. No adaptations of the form and manual are necessary for this. However, the examples can be adjusted to more relevant cases for the mature researchers.

Going back to the design criteria (table 3), the mirror tool is in line with most design criteria. The tool is evaluated on each design criteria in table 6. As can be seen in table 6, the only design criterion which was not met in the tool was “Using the tool should involve stakeholders”. This design criterion involves inclusion, one of the other dimensions of Responsible Research and Innovation. Therefore it was decided that this criterion was less important for a tool for reflexivity and this criterion was neglected in the design. However, reflexivity can be stimulated by getting to know views of others, including the view of stakeholders.

TABLE 6: DESIGN CRITERIA INCLUDING EVALUATION.

Design criteria interviews	In tool	Comment
The tool should be applied to first year’s PhD students	Yes	The tool is best applicable for first year’s students, but also other PhD students and more mature researchers could make use of it.
Using the tool should be a group effort	Possible	It could be a group effort when using the tool for a group project or in collaboration with the PI. However, it could also be used individually.
Principle investigators should be involved when using the tool	Yes	Principle investigators can be involved when using the tool, but it is not necessary.
The tool should be applied at .. (which occasions)	Yes	The tool should be applied when being stuck or at the start of the project.
The tool should be something to do (something active)	Yes	The form has to be filled in actively.
The tool should be concrete, expectations should be made clear	Yes	By using the guideline of the mirror tool, expectations are made clear.
The tool should give feedback	Possible	The tool does not give directly feedback. Although the tool can be used in collaboration with others, stimulating feedback. Also, the folder of the tool can be used to store the forms. When looking back at the forms filled-in earlier, feedback is generated.
There should be pressure to use the tool (by the organisation)	Possible	This can be generated by the way of implementation, described in the outlook.
The tool should be supported by role models (super-users)	Possible	This can be generated by the way of implementation, described in the outlook.
The tool should take you a step back to view the bigger picture	Yes	This is confirmed during the test of the tool.
The tool should be visual	Yes	The tool is in paper form.
Using the tool should involve stakeholders	No	No stakeholders are involved when using the tool, unless these stakeholders are part of the project of the fundamental scientists.
The tool should help considering: “What are you doing? Why? Alternatives? Outcomes?”	Yes	The tool includes these questions, according to the STIR method.
Using the tool experimentation space is needed - openness, elimination of judgement.	Yes	The participants of the test did not feel judged, especially when they could fill it in individually, taking more time for it.
The tool should help taking socio-ethical and socio-economic aspects into account.	Not yet	During the test, no socio-ethical aspects were taken into account. Therefore, a new design was made to force the scientists to think about the ethical considerations.
The tool should facilitate a systematic and disciplined way of thinking.	Yes	The participants of the test liked the structure the tool gives.

As described in the research question, the aim was to create a simple and sustainable tool or method to stimulate reflexivity. This 'simple' tool was defined as being not laborious and easy to use. Meanwhile, the developed mirror tool is simple to use as no social scientists are involved in the process. Besides, even though no facilitator is taking part, handling the tool does not take additional time for the natural fundamental researcher. Furthermore, due to the clear manual attached to the mirror tool, it is also easy to use. Besides, 'sustainable' aims at usefulness of the tool for the scientists. In the test two of the four participants mentioned they would use the tool when it would be available. The other two participants would not use the form, but only the manual as a guide for the process. Therefore, the tool can be considered as simple and sustainable.

In the background section, multiple tools or methods stimulating reflexivity in a midstream mode were described. First of all, the STIR method (Fisher & Schuurbiers, 2013; Flipse & Bayram-Jacobs, 2016; Stolk et al., 2016), which resembles the mirror tool. However, for the STIR method a social scientist is involved, which makes this method interactive, but also very laborious. The mirror form, where no social scientists are involved, is therefore a much simpler tool. Besides, the fundamental scientists are able to use the mirror tool every moment of the day, since it is always available. Therefore, they are still able to modulate their activities real-time. Moreover, using the mirror form, the fundamental scientist can reflect whenever they want instead of at chosen moments with the social scientist, which makes the mirror tool a more open method. The downside of the mirror tool relative to the STIR method is that the questions on the form are very general, since real-time questioning is not possible. However, when discussing the mirror form with the PI after filling it in, this will increase the specificity of the questions.

Besides, sensitization was described as a method for stimulating reflexivity (Penders et al., 2009). By experiencing each other's world, natural and social scientist come closer to each other, stimulating reflexivity. This method resembles the STIR method, only not having a strict protocol. The mirror tool does not involve social scientists, which makes the tool more simple, but also less feedback is given. However, discussing the form with colleagues or the PI will increase the amount of feedback by comparing different perspectives on the problem.

Moreover, a research diary was described as a reflexivity tool (Nadin & Cassell, 2006). A research diary is already implemented at the TU Delft, as being a logbook. However, using a research diary no pressure is on ethical and societal considerations of research. Therefore, only scientific considerations will be taken into account when using this research diary. Using the mirror tool, also ethical considerations will be taken into account as space is created for this on the form.

Also, playfulness was mentioned as a possible method for stimulating reflexivity. This method can make use of four different activity principles: narration, imagination, action-reflection and co-creation (van der Meij et al., 2017). Two of the four activity principles are also used in the mirror tool: action-reflection and co-creation. Action-reflection is used by writing down the consequences, alternatives and outcomes. Co-creation is only used in the creation of the method. Besides, narration can be used by discussing the mirror form with the PI, as was advised by the interviewed PI. Also, imagination can possibly be used to find alternatives for the solutions, especially in collaboration with others. In this way, playfulness is partially integrated in the design of the mirror tool.

The last method for stimulating reflexivity was real-time technology assessment (Guston & Sarewitz, 2002). This method is focussed on the end-product of the innovation. However, in fundamental science

the end product is knowledge gain or not yet well-defined. So, apart from reflection this method aims at anticipation. Therefore, this method is very different from the mirror tool. However, the components of real-time technology assessment could be useful to come up with ethical considerations when filling in the mirror form.

The newness of the tool, in comparison to the other described tools, is centred in its simplicity. First of all, the fundamental scientists are able to use the mirror tool at every moment of the day, since it is always available. Besides, the mirror form and the attached manual are concrete and expectations are made clear, making it easy to use and simple. Lastly, the tool is not laborious for natural or social scientist, unlike the STIR method and sensitization, making it a simple tool.

As been mentioned in the background, researchers think RRI is important, but often do not apply it. This is due to the fact that 1) scientists think non-scientists are uninformed on the research and therefore could not provide useful input, 2) the field they work (for example fundamental sciences) is not suitable for RRI and 3) another bureaucratic layer will be added by RRI (Böger et al., 2017). With the mirror tool, these conceptions should be taken away. First of all the mirror tool does not aim at engagement, so the first reason of not using the tool can be rejected. Secondly, the mirror tool was seen as useful by the participants of the test, proving the second reason wrong. Lastly, by implementing the mirror tool, no extra bureaucratic layer is implemented since it is a voluntary tool, which can be used whenever you want. In this way, these scientists' reservations are refuted, hopefully solving the issue of researchers thinking RRI is important, but not applying it.

5.2 Discussion of the methodology

The methodology used in this thesis project is a unique one. For the first time, together with the end-users, the scientists, a tool was made for Responsible Research and Innovation. A combination of co-design and the design methodology of the British design council was used to create a tool.

However, the methodology of this thesis differed from the standardized way of the British Design Council (UK Design Council, 2007). This was mostly due to the limited time of the participants during the co-design session. First of all, the scenario step was skipped and instead concepts were generated after creating the morphological chart. When inserting a scenario step, first general scenarios are generated and afterwards specific concepts. This can help taking more solutions of the morphological chart into account. However, in this study, the solutions on the morphological chart were taken into account when creating the concepts by specifically reading the morphological chart and afterwards coming up with solutions. Therefore, in my opinion, the concepts are equally valuable as when inserting a step of scenario generation in between. Secondly, no second morphological chart was made after picking the best concept. However, this was compensated by talking over the design with two designers. Therefore, several options for the design were discussed. In this way, the standardized way of designing according to the British Design Council is differed from, but all important aspects have been taken into account.

Using the co-design method, three different perspectives - of the expert (end-user), the designer and the social scientist - were considered for concept generation. Therefore, this is an addition to a normal design method with only social scientists. But is this co-design method better than a design method involving only social scientists? First of all, the vision of the end-users are taken into account.

Furthermore, the view of all participants is broadened by the different perspectives which can probably result in more innovative and better concepts. However, further research is necessary for a conclusive answer on this question.

5.3 LIMITATIONS OF THE RESEARCH

In this section, limitations of the research are discussed per methodology step. Subsequently, the limitations will be discussed of the literature research, the interviews, the co-design session, the concept generation and the test.

5.3.1 Literature research

For the background section, it was chosen to do a narrative literature research, since several topics had to be introduced and not reviewed. In this way, most important and most relevant literature is found. However, Google Scholar was used as a search engine. Using this search engine, not only peer-reviewed papers can be found, but everything which is published and available on the internet could be found. Therefore, references where securely picked considering the date, amount of citations and place published. Trying out the same search terms for Web of Science as used for Google Scholar, only a few search results appear for Web of Science, partially overlapping with the results from Google Scholar and partially irrelevant.

All design criteria from literature for the tool were found in the background section. However, it is not sure all criteria are found using this method, since no structural method was applied. Although, since all themes considering the research question were covered in the background section, most criteria for reflexivity will also be found. Therefore, this narrative approach was in this manner a suitable method for finding the design criteria on reflexivity.

Besides, reflexivity tools were found using this method. Therefore, probably not all available reflexivity tools are found. However, this was not the goal of the research. The goal was to get an overview of different kinds of methods now used for stimulating reflexivity. Besides, the mentioned methods are not specifically aimed at fundamental scientists, but at applied or all scientists. Also playfulness is not specifically aimed at the research community. However, these methods all stimulate reflexivity midstream, according to the starting points described in the introduction.

5.3.2 Interviews

The interviews were performed with four participants in fundamental research from different research groups and different nationalities. The small number of participants is due to the exploratory nature of this research. Furthermore, this is a qualitative research and a diversity of participants was used, making the results still reliable.

The interviews were transcribed and open coded. This means there were some pre-set codes, but also emergent codes were formulated during the coding of the transcripts. When new codes were added, the previously coded text was reviewed to search for quotes applying to this same code. Freedom in interpretation was taken, so in some occasions the quotes concerning the same code did not have exactly the same intonation. However, the meaning of the statements were similar, like “Because this would be something that people definitely would procrastinate, if it is not very concrete” and “It has

to be down to earth, down to exactly what people are doing" being both quotes belonging to the code 'concrete'. This was tried to keep objective by securely attaching quotes to codes (appendix 5).

5.3.3 Co-design

In the co-design method solutions of the design criteria were formulated using the 'how to?' questions. Afterwards, the favourite, most feasible and most innovative solutions were chosen and stuck on the morphological chart. This step directly followed into the concept generation step, meaning the step of creating scenarios was skipped. However, first creating scenarios and afterwards generating concepts would need another session. Since the participants had limited time, this would be impossible. Furthermore, since the participants were explicitly asked to use the morphological chart when generating concepts, the solutions of the design criteria were taken into account for each concept. In the way, the scenario generation step was merged into the concept generation step.

For the co-design method three participants were invited of which one designer, one expert (the fundamental researcher) and one guider/social expert. On the one hand, this is the way it was suggested by literature (Sanders & Stappers, 2008). On the other hand, the expert is the most important stakeholder and at the same time the end-user. Therefore, more experts participating in the co-design session would have been better to be able to generate more and better solutions.

During the co-design session, observations were done to study how a co-design method would help in creating a tool for reflexivity. The observations were not well prepared. However, the goal of this part of the research was to explore and not to prove. In the end, the observations were in line with literature, resulting in different perspectives on the problem and coming up with various solutions on the morphological chart, broadening the view of all participants. However, in order to provide a more consistent conclusion, more research should be done.

Concept generation was first done with the three participants of the co-design method. Afterwards, two other participants helped creating concepts. The experts participating with generating concepts also participated in the interviews. During the interviews I explained the concept of STIR as an example of a reflexivity tool. This means the only reflexivity tool they knew, when generating concepts, was the STIR method. Therefore, although they were stimulated to come up with new concepts, they could be biased by this example I gave. Therefore, it would have been better to use another group of participants for the concept generation than for the test. In that way, the participants would probably more open-minded. However, it was not feasible to use another group of participants as this would have cost a lot of time, explaining them the concepts and research. Besides, the STIR method is a proven tool, making it a reliable starting point of the mirror tool.

5.3.4 Test

The goal of the test was to improve the tool based on experiences of the four participants and to test whether to tool could stimulate reflexivity. As it became clear in the group interview that all four of them ran into almost the same problems, this test was large enough for improving the tool. However, to be able to reliably test to what extent the tool could stimulate reflexivity, more participants are necessary.

After using the tool by the participants, a semi-structured group interview was performed. An important task of the interviewer during the group interview was to monitor the group process. Therefore, I ensured that everyone took part in the discussion. However, after transcribing the

interview, I observed that participant 1 and 2 were in charge most and participant 3 and 4 were less. This could have influenced the overall opinion of the group. However, participants 3 and 4 still took part enough to take their opinion into account.

5.4 OUTLOOK ON THE TOOL

In this outlook on the tool subsequently the implementation, further research and generalization of the tool will be discussed. Afterwards the value for NUCLEUS will be presented.

To implement the mirror tool at the BN department two options were given by the interviewed PI: through courses for first year's PhD students in the graduate school or give it to the PIs and convince them to use the tool. I propose to first create awareness and engagement amongst the PIs. If they support the concept, they should be trained to use the mirror tool well, including getting commonly known with RRI. In this way, the PIs will act as ambassadors or super-users, being able to give feedback to the PhD students. Afterwards it is introduced by the graduate school and by the ambassadors to the PhD students in their first year. In this way, the PhD students will also start to use it as they look up to their PI, like a participant of the interviews said: "Especially if you would have a PI that does something like this, it would be a stronger statement. Because they have already proven themselves as a scientist".

Further research is necessary to make the tool more reliable. The interviewed PI mentioned that when the effect of the tool would be scientifically proven, the tool would be more reliable and more used. Therefore, quantitative tests of the tool should be performed to statistically prove the effect of the tool before implementation.

Besides, the tool could be more functional when digitalizing the mirror form. In this way, future users will not be limited by the amount of writing space. In the test of the tool it was mentioned that due to the writing limitations they did not take the socio-ethical and socio-economic aspects into account. Also, when digitalizing the tool supplementary elements can be implemented, like a helpdesk function or a competitive element. However, to implement these adjustments during this research was not possible, as the means and knowledge to provide such a website or application were not available. Therefore, this needs to be outsourced in order to further develop the tool.

For now, the mirror tool was developed and tested at the BN department of the TU Delft. However, such a tool could probably be useful for more scientists of other departments and universities. The group of participants for the interviews and test was composed of individuals from different nationalities, different research groups and in different fundamental topics within natural sciences. Besides, the tool will be aimed for first year's PhD students (having different backgrounds). Therefore, the tool could possibly be generalized throughout other departments and universities. However, this was an exploratory research, so creating a general tool was not the intention. Therefore, to make a more generalizable tool, a large-scale test would be necessary. First of all, the tool could be tested with fundamental scientists within the TU Delft in various research fields, like quantum nanoscience. Another option is to test the tool with fundamental natural scientists of other institutions than the TU Delft. Besides, the tool could be reviewed with fundamental scientist of other institutions than the TU Delft in various research fields. Lastly, the tool could be reviewed with applied scientists.

The mirror tool and the new co-design method to create such a tool could be of large value for the NUCLEUS consortium. First of all, the mirror tool itself can be distributed by the consortium members in their university to increase reflexivity within these universities. Additionally, the new co-design method used in this thesis could be used by consortium members to create tools for RRI in collaboration with the scientists themselves. Using the one page guideline (appendix 17), consortium members can easily create a tool for RRI for their specific target group and in their context.

6. CONCLUSION

In this chapter, the answers to the sub-research questions are given and afterwards the answer to the main research question.

6.1 ANSWER TO SUB-RESEARCH QUESTIONS

To what extent is reflexivity a suitable dimension of Responsible Research and Innovation for fundamental scientists?

One of the theories on Responsible Research and Innovation states that it in practice consists of four dimensions: anticipation, inclusion, reflexivity and responsiveness (Stilgoe et al., 2013). Reflexivity is considered as the most relevant dimension of RRI for fundamental scientists, since these scientists are far away from the application part of research. Therefore the dimensions anticipation and inclusion seem to be less relevant, since these dimensions are focussed on the outcome. Furthermore, the fourth dimension, responsiveness, can be the result of reflexivity, since to determine what choices will lead to ethical, socially desirable and sustainable futures, one should first reflect on the current situation and the potential future (Flipse et al., 2013b).

In the interviews of this study, fundamental scientists were asked to comment on the four dimensions of responsible research and innovation. Each participant had a different opinion on the four dimensions. However, most of them mentioned no connection was found with anticipation. Besides, all of them recognized the importance of being reflexive.

On the mirror form, the last question “So what?” is not stimulating action. Therefore, it is not stimulating reflexivity, but responsiveness. The participants of the test session of this study were asked about the added value of this question. They mentioned this was even the essence of the tool: “That is in the end what you are doing it for”.

Therefore, the dimension reflexivity seems to be most suitable dimension of RRI for fundamental researchers. However, only thinking different is not enough, acting different is the end-goal. Therefore, responsiveness is another important dimension of RRI for fundamental researchers.

Which motives do fundamental scientists have for being reflective or not?

Three different kinds of motivations of scientists were found in literature on RRI: normative, instrumental and substantive (Sykes & Macnaghten, 2013) (Stirling, 2008) (Flipse et al., 2013b). Normative motivation results in carrying a social responsibility and moral duty. However, scientists have difficulties identifying the social impact being unaware of the broader social and ethical context. Instrumental motivation relates to ways of building trust or avoiding adverse public reaction. Substantive motivation aims at achieving generally better ends. Researchers can have the motivation for RRI if they consider societal and ethical aspects improving the quality of their research.

The fundamental participants in the interviews of this study gave four different reasons for being reflexive: 1) it is important for keeping motivation, 2) you have a certain responsibility using the tax

money, 3) it is necessary in order to get good result for articles and 4) it is more time efficient. These motivation are in line with the normative and substantive motives mentioned in literature.

Previous research on reservation of fundamental scientists for RRI showed that fundamental research is viewed as not socially relevant (Böger et al., 2017). Scientists believe the distance between the research and the public is too big for meaningful input and fundamental research should proceed without intervention.

The motives for being reflexive mentioned by the interviewees seem to be mostly relevant for micro-ethics, except for using tax money, whereas the reservations for RRI are mostly based on macro-ethics. Therefore, it seems fundamental scientists are more motivated for first-order reflexivity, but less for second-order reflexivity. This is also supported by the test results, since during the test session the participants did not take any socio-ethical or socio-economic consequences of their projects into account at all. However, both orders of reflexivity are important for responsible research and innovation, so also second-order reflexivity needs be stimulated for the fundamental researchers.

What kind of methods or tools for stimulating reflexivity are currently available?

In literature on reflexivity tools no methods or tools were found specifically addressing fundamental scientists. The reflexivity tools found in literature were the STIR method, sensitization, the research diary, playfulness and real-time technology assessment. First of all, STIR is a collaborative approach of researchers involved in natural sciences and social sciences to stimulate RRI. Reflexive learning is being stimulated by STIR. Secondly, sensitization is stimulating reflexivity by bringing natural and social scientists together, experiencing each other's world. Furthermore, using a research diary provided time, space and context to be reflexive. Moreover, playfulness is a mode of working to stimulate reflexivity. This can be performed through narration, imagination, action-reflection and co-creation. Lastly real-time technology assessment is assessing the technology midstream, focussing on the societal impact of the end product.

Probably more tools for reflexivity are available. However, a few examples were enough to get a good idea of what kind of methods or tools are available. These insights were used for designing the tool to stimulating reflexivity.

How does a co-design method help in creating a tool stimulating reflexivity?

Theory describes co-design as a form of co-creation, where co-creation is applied along a process of designing. Three roles can be found in a co-design process: 1) the expert or user, playing a large role in knowledge, idea and concept development, 2) the (social) researcher, playing a role by providing tools for ideation and expression and 3) the designer, giving form to the ideas of the expert (Sanders & Stappers, 2008). Steen et al (2011) found many benefits of co-design. For example, higher satisfaction and higher loyalty of costumers was found, which can help with the implementation of the product. Furthermore, the quality was higher and more successful innovations were founded (Steen et al., 2011).

During the co-design process of this study, it was observed that due to this collaboration (including the three roles), multiple views on the same question or problem were found. This resulted in an open-minded discussion and generation of many different solutions. This was also supported by the results of picking the most feasible, most innovative and favourite solutions. When picking the most favourite solutions most often the solution of the expert was chosen, when selecting the most feasible solution, mostly the solution of the social scientist was chosen and when choosing the most innovative solution, most often the solution of the designer was picked.

Therefore, the co-design methods seems to help finding more creative solutions, taking views of different stakeholders into account. This can lead to higher quality and more successful innovations. However, this is not proven by this study, so future research on this topic is necessary.

6.2 Answer to main research question

To what extent can reflexivity amongst PhD students in fundamental research within the TU Delft be stimulated with a simple and sustainable tool or method?

In this study, a simple and sustainable tool, called the mirror tool, is designed via a self-developed co-design method with the aim to stimulate reflexivity amongst scientists in fundamental research within the TU Delft. This mirror tool was co-designed and tested with fundamental scientists of the department of bionanoscience of the TU Delft.

On micro-ethics level (first order) reflexivity seemed to be stimulated by using the tool. All participants of the test in this study agreed that the most useful part was visualizing the alternatives, as this could help brainstorming and thinking through the project. Especially first year's students mentioned the form would help guiding them when reflecting on bigger projects or when being stuck. The senior PhD students indicated they would not need the form to be more reflexive. However, the manual was useful as a guide for being reflexive. Already during the semi-structured interviews of this study it was mentioned stimulating reflexivity would be most useful for first year's PhD students, since it is also a process which you can learn during the course PhD project.

However, while first order reflexivity seemed to be stimulated, macro-ethics were not considered, omitting the socio-ethical and socio-economic aspects. Therefore, changes to the design are proposed assuring also macro-ethics will be considered. This includes adding a box to separate the consequences. One box will be for the scientific consequences, as the scientists think this is the most useful, and one box will be for the socio-ethical and socio-economic consequences. In this way, the scientists still think it is worth it to fill in the mirror form (micro-ethics), but they are also forced to think about the macro-ethics.

Unlike the previous point, another criteria for reflexivity - facilitating a systematic and disciplined way of thinking - was stimulated, according to the participants of the test session. Besides, the test participants also felt they had quite some experimentation space. However, they felt limited by the time and writing space. Therefore, it is proposed to digitalize the mirror form to facilitate unlimited writing space.

Also, a PI can be involved using the mirror tool. The PhD student can discuss the filled-in form with the PI. However, filling in the form together with the PI was not considered as useful, as it will take a lot of time of the PI. Even though, filling in the form together with colleagues working on a shared project would be useful to verbalized your thoughts.

Using the tool, not only reflexivity will be stimulated, but also responsiveness will be encouraged, due to the last question ‘So what?’. In this way, not only learning and thinking will be different, but also adjustments can be made to the current way of working.

7. REFERENCES

Böger, E., Carrier, M., Gartzlaff, M., & König, R. (2017). *NUCLEUS Survey Result Report*. Retrieved from nucleus-project.eu:

Burget, M., Bardone, E., & Pedaste, M. (2017). Definitions and Conceptual Dimensions of Responsible Research and Innovation: A Literature Review. *Sci Eng Ethics, 23*(1), 1-19.

Dewey, J. (1933). *How we think*. Buffalo: NY: Prometheus Books.

Engineering and physical sciences research council. (2018). Anticipate, reflect, engage and act (AREA). Retrieved from https://www.epsrc.ac.uk/research/framework/area/

Expert Group on Policy Indicators for Responsible Research and Innovation. (2015). *Indicators for promoting and monitoring Responsible Research and Innovation*. Retrieved from http://ec.europa.eu/research/swafs/pdf/pub_rri/rri_indicators_final_version.pdf:

Finlay, L. (2002). "Outing" the Researcher: The provenance, Process, and Practice of Reflexivity. *Qualitative Health Research, 12*(4), 531-545.

Fisher, E. (2007). Ethnographic Invention: Probing the Capacity of Laboratory Decisions. *NanoEthics, 1*(2), 155-165.

Fisher, E., Mahajan, R. L., & Mitcham, C. (2006). Midstream Modulation of Technology: Governance From Within. *Bulletin of Science, Technology & Society, 26*(6), 485-496.

Fisher, E., & Maricle, G. (2014). Higher-level responsiveness? Socio-technical integration within US and UK nanotechnology research priority setting. *Science and Public Policy, 42*(1), 72-85.

Fisher, E., & Schuurbiers, D. (2013). Socio-technical Integration Research: Collaborative Inquiry at the Midstream of Research and Development. In *Early engagement and new technologies: Opening up the laboratory* (pp. 97-110).

Flipse, S. M., & Bayram-Jacobs, D. (2016). RRI bridges science education and communication. In M. C. A. v. d. Sanden & M. J. d. Vries (Eds.), *Science and technology education and communication* (Vol. 15, pp. 147-162): Sense publishers.

Flipse, S. M., & van der Sanden, M. C. (2016). Interaction design for RRI. Powerpoint Presentation: NUCLEUS conference.

Flipse, S. M., van der Sanden, M. C., & Osseweijer, P. (2013a). Midstream modulation in biotechnology industry: redefining what is 'part of the job' of researchers in industry. *Sci Eng Ethics, 19*(3), 1141-1164.

Flipse, S. M., van der Sanden, M. C., & Osseweijer, P. (2013b). The why and how of enabling the integration of social and ethical aspects in research and development. *Sci Eng Ethics, 19*(3), 703-725.

Friedman, B. (1996). Value-sensitive design. *Interactions, 3*(6), 16-23.

Gerber, A. (2014). NUCLEUS - New Understanding of Communication, Learning and Engagement in Universities and Scientific Institutions. In. Horizon 2020: European Commission.

Glerup, C., & Horst, M. (2014). Mapping 'social responsibility' in science. *Journal of Responsible Innovation, 1*(1), 31-50.

Goodin, R. E., & Dryzek, J. S. (2016). Deliberative Impacts: The Macro-Political Uptake of Mini-Publics. *Politics & Society, 34*(2), 219-244.

Groves, C. (2017). Review of RRI tools project. *Journal of Responsible Innovation*, 1-4.

Guston, D. H., & Sarewitz, D. (2002). Real-time technology assessment. *Technology in Society, 24*(1-2), 93-109.

Herkert, J. R. (2005). Ways of thinking about and teaching ethical problem solving: Microethics and macroethics in engineering. *Science and engineering ethics, 11*(3), 373-385.

Kerr, A., Cunningham-Burley, S., & Tutton, R. (2016). Shifting Subject Positions: Experts and Lay People in Public Dialogue. *Social Studies of Science, 37*(3), 385-411.

Keutel, K., & van Hattum, J. (2017). *Inclusion in Physics Post-Doctoral Research*. TU Delft.

Kupper, F., Klaassen, P., Rijnen, M., Vermeulen, S., & Broerse, J. (2015). *Report on the quality criteria of Good Practice Standards in RRI*. Retrieved from Athena Institute, VU University Amsterdam

Lee, S. M., Olson, D. L., & Trimi, S. (2012). Co-innovation: convergenomics, collaboration, and co-creation for organizational values. *Management Decision, 50*(5), 817-831.

Mitcham, C. (2003). Co-responsibility for research integrity. *Science and engineering ethics, 9*, 273-290.

Nadin, S., & Cassell, C. (2006). The use of a research diary as a tool for reflexive practice. *Qualitative Research in Accounting & Management, 3*(3), 208-217.

Owen, R., Macnaghten, P., & Stilgoe, J. (2012). Responsible research and innovation: From science in society to science for society, with society. *Science and Public Policy, 39*(6), 751-760.

Owen, R., Stilgoe, J., Macnaghten, P., Gorman, M. E., Fisher, E., & Guston, D. (2013). A Framework for Responsible Innovation. In R. Owen, J. Bessant, & M. Heintz (Eds.), *Responible innovation* (1 ed.): John Wiley & Sons.

Payne, A. F., Storbacka, K., & Frow, P. (2007). Managing the co-creation of value. *Journal of the Academy of Marketing Science, 36*(1), 83-96.

Penders, B., Vos, R., & Horstman, K. (2009). Sensitization: reciprocity and reflection in scientific practice. *EMBO reports, 10*(3), 205-208.

Prahalad, C. K., & Ramaswamy, V. (2004). Co-creation experiences: The next practice in value creation. *Journal of Interactive Marketing, 18*(3), 5-14.

Rip, A. (2014). The past and future of RRI. *Life Sciences, Society and Policy, 10*(17).

Rodgers, C. (2002). Defining reflection: Another look at John Dewey and Reflective thinking. *Teachers college record, 104*(4), 842-866.

RRI tools. (2018). RRI. Towards an open science and innovation system that tackles societal challenges.

Sanders, E. B. N., & Stappers, P. J. (2008). Co-creation and the new landscapes of design. *CoDesign, 4*(1), 5-18.

Schot, J., & Rip, A. (1997). The Past and Future of Constructive Technology Assessment. *Technological Forecasting and Social Change, 54*, 251-268.

Schuurbiers, D. (2011). What happens in the lab does not stay in the lab [corrected]: Applying midstream modulation to enhance critical reflection in the laboratory. *Sci Eng Ethics, 17*(4), 769-788.

Schuurbiers, D., & Fisher, E. (2009). Lab-scale intervention. *EMBO reports, 10*(5), 424-427.

Smeets, M., Baas, L., & de Jong, V. (2017). *The perception of researchers in innovative research and development processes on Responsible Research and Innovation*. TU Delft.

Steen, M., Manschot, M., & de Koning, N. (2011). Benefits of Co-design in service design projects. *International Journal of Design, 5*(2), 53-60.

Stenfert, H. (2017). *Cocreation in housing design.* (Master Thesis), TU Delft, Repository TU Delft.

Stilgoe, J., Owen, R., & Macnaghten, P. (2013). Developing a framework for responsible innovation. *Research Policy, 42*(9), 1568-1580.

Stirling, A. (2008). “Opening Up” and “Closing Down”: Power, Participation, and Pluralism in the Social Appraisal of Technology. *Science, Technology, & Human Values, 33*(2), 262-294.

Stolk, K., Fisher, E., & Flipse, S. M. (2016). *Guidelines to perform a socio-technical integration research project*. Arizona State University & Delft University of Technology.

Sykes, K., & Macnaghten, P. (2013). Responsible Innovation - Opening Up Dialogue and Debate. In *Responsible Innovation* (pp. 85-107).

UK Design Council. (2007). *Eleven lessons: managing design in eleven global companies*. Retrieved from www.capitalsynthesis.com/wp-content/uploads/2011/07/Design_Process_Report1.pdf:

van der Meij, M. G., Broerse, J. E. W., & Kupper, F. (2017). Conceptualizing playfulness for reflection processes in responsible research and innovation contexts: a narrative literature review. *Journal of Responsible Innovation, 4*(1), 43-63.

von Schomberg, R. (2011). Prospects for Technology Assessment in a framework of responsible research and innovation In M. Dusseldorp & R. Beecroft (Eds.), *Technikfolgen abschätzen lehren: Bildungspotenziale transdisziplinärer Methoden*. Wiesbaden: Vs Verlag.

Von Schomberg, R. (2013). A vision of Responsible Research and Innovation. In R. Owen, M. Heintz, & J. Bessant (Eds.), *Responsible innovation*.

Wenger, E. (2000). Communities of Practice and Social Learning Systems. *Organization, 7*(2), 225-246.

Wesselman, D. (2017). *Real time communication in shipbuilding.* (Master Thesis), TU Delft, Repository TU Delft.

Wilford, S. H. (2015). What is required of requirements? A first stage process towards developing guidelines for responsible research and innovation. *SIGCAS Computers & Society, 45*(3), 348-355.

Wilsdon, J., & Willis, R. (2004). *See-through Science: Why public engagement needs to move upstream*. Retrieved from Demos:

Wynne, B. (2011). Lab work goes social, and vice versa: strategising public engagement processes : commentary on: "What happens in the lab does not stay in the lab: applying midstream modulation to enhance critical reflection in the laboratory". *Sci Eng Ethics, 17*(4), 791-800.

Zwart, H., Landeweerd, L., & van Rooij, A. (2014). Adapt or perish? Assessing the recent shift in the European research funding arena from 'ELSA' to 'RRI'. *Life Sciences, Society and Policy, 10*(11), 19.

8. APPENDIX

APPENDIX 1. LITERATURE STUDY

TABLE 7: LITERATURE STUDY USING KEY WORDS.

Literature on:	Key words	Literature found
RRI	Responsible research and innovation	(R. Owen et al., 2012)
		(von Schomberg, 2011)
Reflexivity	Reflexivity Responsible research and innovation	(Stilgoe et al., 2013)
		(Richard Owen et al., 2013)
	Reflexivity RRI	(Zwart et al., 2014)
		(Rip, 2014)
		(Groves, 2017)
		(Flipse & Bayram-Jacobs, 2016)
	Reflective thinking	(Rodgers, 2002)
	Reflexivity scientists	(Wynne, 2011)
Existing RRI tools	Tool reflexivity of researchers	(Finlay, 2002)
		(Nadin & Cassell, 2006)
Midstream Modulation	Midstream modulation	(Fisher et al., 2006)
		(Schuurbiers, 2011)
		(Schuurbiers & Fisher, 2009)
		(Fisher & Schuurbiers, 2013)
		(Fisher, 2007)
		(Flipse et al., 2013a)
		(Wynne, 2011)
	Sociotechnical integration research	(Fisher & Maricle, 2014)
Co-design	Co-design shared value	(Sanders & Stappers, 2008)
	Co-creation shared value	(Prahalad & Ramaswamy, 2004)
		(Lee et al., 2012)
	Co-design value	(Payne et al., 2007)
		(Steen et al., 2011)
	Design value	(Friedman, 1996)
Design criteria RRI	Indicators RRI	(Expert Group on Policy Indicators for Responsible Research and Innovation, 2015)
		(Kupper et al., 2015)

Snowball method:

TABLE 8: ARTICLES FOUND USING THE SNOWBALL METHOD.

Starting article	Articles found
(Stilgoe et al., 2013)	(Fisher et al., 2006)
	(Fisher, 2007)
	(Mitcham, 2003)
	(R. Owen et al., 2012)
	(Wilsdon & Willis, 2004)
	(Schot & Rip, 1997)
	(Goodin & Dryzek, 2016)
	(Schuurbiers & Fisher, 2009)
	(Schuurbiers, 2011)
	(von Schomberg, 2011)
	(Kerr et al., 2016)
	(Wynne, 2011)
	(Guston & Sarewitz, 2002)
	(Stirling, 2008)
(R. Owen et al., 2012)	(Sykes & Macnaghten, 2013)
(Schuurbiers, 2011)	(Herkert, 2005)
RRItools.eu	(Burget et al., 2017)
	(Glerup & Horst, 2014)
	(RRI tools, 2018)
	https://cns.asu.edu/research/stir/howto
(Burget et al., 2017)	(Wilford, 2015)
	(Schuurbiers, 2011)
	(von Schomberg, 2011)
	(Von Schomberg, 2013)
(Rodgers, 2002)	(Dewey, 1933)

APPENDIX 2. INTERVIEW PROTOCOL SEMI-STRUCTURED INTERVIEWS

Introduction

Welcome to this interview. In the next hour I will ask you about Responsible Research and Innovation, which I will tell more about soon. The purpose of this interview is for me to obtain new insights in reflexivity of fundamental researchers. I would like to record the interview if that is okay by you. This recording will only be used for educational reasons, and the recording nor the information you give to me will be spread.

Back-ground information

Date:
Name:
Experience?
Shortly, what is your research about?

RRI

What does Responsible Research and Innovation mean for you?

Von Schomberg (2011): "**Responsible Research and Innovation** is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society)". Therefore, the goal of RRI is that scientists will see embedding in society as part of their profession. Four dimensions of RRI are defined: anticipation, reflexivity, inclusion and responsiveness. **Anticipation** is mostly found at the start of the research asking "What if?". **Reflexivity** is an aspect occurring during the research trying to rethink prevailing conceptions. **Inclusion** is involving stakeholder as part of a search for legitimacy. **Responsiveness** can be described as reacting on changing circumstances by changing direction of the innovation. This is therefore the act on the previous three aspects. So in short, RRI is the process of thinking about the social and ethical aspects of the research.

Do you feel comfortable with RRI? Why?
Do you feel responsible with one of the four dimensions? Which? Why (not)?
Which of the four dimensions do you incorporate in your work? Why? Can you give some examples of this?

Reflexivity

My research is focused on reflexivity, the second dimension of RRI. This means reflecting on your activities or **self-awareness** by for example rethinking prevailing conceptions. You can think of asking yourself what are you doing, why you are doing something, thinking of alternatives and what outcome that would have. This could be done midstream, which means during the research (not before or after).

Do you feel responsible to be reflexive? Why?
Can you give examples of being reflexive in your work?
Do you feel the need to be more reflexive in your work? And why?
Do you need training for this? Or do you see this as a process?
What are the constraints of being reflexive within your research group or faculty?

How do your colleagues think about being reflexive?

Reflexivity tool or method

I am thinking of making a tool or method for fundamental researcher for being more reflexive with regard to the social ethical context of their research. A common method now used is STIR, which is a collaborative approach of researchers of natural sciences and social sciences to stimulate Responsible Research and Innovation. For a period of 12 weeks, a social scientist cooperates with natural scientists to engage them with the social and ethical relevant aspects of their work. Iterative sessions will be held one on one by asking question like: what are you doing, why you are doing something, thinking of alternatives and what outcome that would have. This method already showed some positive results on reflexivity. However, this method is very laborious and therefore I want to create a simple tool or method to overcome this. This does not mean you are not incorporating it now. I just want to find out if this is something which will be helpful or not for fundamental researchers.

What are your first thoughts about this?
Do you think such a tool or method could be helpful for being more reflexive in your daily work?
Do you think such a tool is useful?
In what occasions would you like to use the tool/method?
How often would you like to use the tool/method? And how long per time?
Under which circumstances would you like to use such a tool?
Do you want to work with the tool/method alone? Or together?
Should the tool/method be something to do? Or something to think about?
Further requirements tool/method.

Closing

Thank you very much for your time and participation in this interview. Would you like to help me once more, finding out the design criteria and filling this in into a morphological chart?

APPENDIX 3: TRANSCRIPTS SEMI-STRUCTURED INTERVIEWS

Interview 1

RRI

What does Responsible Research and Innovation mean for you?
"Reading this, I mean of course I know these things, I just didn't know the term."

Do you feel comfortable with RRI? Why?
"Well, it makes a lot of sense. In my view, this is how it should be. But in a lot of cases it is not." "This is kind of an idealist situation."

Do you feel responsible with one of the four dimensions? Do you feel like you have to do something with it? Which? Why (not)?
Communication to the public. Being careful about what to say about who. Explanations to the public.

Which of the four dimensions do you incorporate in your work? Why? Can you give some examples of this?
What if experiments don't work? Fundamental research: think about who can use it? Where does it go? "In the end, fundamental research is not just for the sake of knowing stuff. It has to be useful in the end anyway."
Reflexivity: always same techniques to use. "But also if you start to get results that are different from famous published papers. Then you start to think, hmm, is it me or is it them? Or why am I seeing this? Is it because I am using a different technique that they could not see this with their technique." Well, I think especially with the techniques I mean, you need to think of ok, people use this technique. But is this the best technique, maybe ours is better or theirs is better. Sort of open mind.

Reflexivity

Do you feel responsible to be reflexive? Why?
"Especially because I am doing a PhD, a lot of the times if you don't like start thinking of the bigger picture, ok, I am doing this, then you can really lose motivation because you know things don't work for months." "so it is also just like for myself"

And I also actually think it is also something you are already doing in your work but you don't really thinking about it all the time probably.
I think so. "The most of the times, you chose which way is the quickest. But then, you are ok, I should have done the longer way." Also a lot of the time, you start your experiment and midstream of the experiment you think I should change this or change that.

Do you feel the need to be more reflexive in your work? And why?
"I think I am much more reflexive now than I was three years ago."

And do you think training in this will work? Or is it just a process?
"I think for PhD students it might be useful, cause we a lot of the times just tend to get lost in the details and really get stressed out and lose the bigger picture. Lose the importance of what we are doing here, we are doing here to find out something new, something unknown and not necessarily you know, we have a hypothesis you go in there. If it does not work according to your hypothesis and you feel sad, but then you know you need to take a step back and think actually, but this is also new. That's why I am saying. Three years ago I was really stressed, getting really lost in the details and not taking a step back and like looking at my work and not actually, what am I actually doing?

What are the constraints of being reflexive within your research group or faculty?
I am lucky with my boss. When I was getting really lost in the details he would say it will work and I would come in and I don't like this results. "It kind of trains you indirectly to look at it from different views." But I mean in some research groups they are really pushed for results and perhaps you get this and this amount of time and I mean you get so stressed, you don't think about ..". Also at the TU Delft, even at BN.

How do your colleagues think about being reflexive?
Some people are more than others. And especially you can also see this difference between people who are in fourth year or people who are in first year.

Reflexivity tool or method

What are your first thoughts about this?

Different scales of reflexivity. "It is also when you are starting in your first year you think you are going to change the world. And then you realize it is not like that."

In general, fundamental natural scientists are more likely or have more tendency to overlook ethical aspects for the greater good. So I don't know to have a social scientists around with help, it's like hmm…

A form where it is just basically, scientists should not play god. (..) Think about the consequences, cause if you are able to do sth like this, it is kind of playing god a bit. I don't know, if you are in the lab and things go well, and you are a big PI, it is easy to think like nothing has consequences.

With the general public you need to be very careful of what say to them. Listening to the general public: what is the demand? What are they afraid of?

Do you think such a tool or method could be helpful for being more reflexive in your daily work?

On this scale, if you have something to remind you of why are you

"It is almost like drawing a mindmap."

Do you think this is useful?

I think it is useful, because people do get lost in the details and if sth doesn't work you can spend 6 moths working on sth which is not going to work or you just look over a simple detail and just because you are to focused

Something to take a step back, put everything on sth where you could see.

How often would you like to use the tool/method? And how long per time?

When things don't work or when you just finish or start a project.
When you are to focused on the small thing and lose the bigger picture. Also when writing a paper.

Do you realize when you are too focused?

I think it takes time and experience. But in the end you do. If you are working on the same experiment for weeks and weeks and it is not working and you are not doing anything else at all, than you might be too focused.

Do you want to work with the tool/method alone? Or together?

For a group once half a year, once a year, it is useful to sit down. We also did it for the lab. Thinking of the lab direction, what should we change. Also group dynamics, research dynamics.
Group: takes time to implement.

Should the tool/method be something to do? Or something to think about?

Program/app, where you can draw, not necessarily a mind map, but sort of like, what am I doing, what have I done. Like a one page. Especially visual. As you can always go back to it.

Further requirements tool/method.

I don't know. I think it is different for everyone. Depends which years people are in. Because also now we have to think of the best way to do the best way of experiments because we have to finish soon. So there is less room for error. So need to take a step back as soon as sth doesn't work.

It is also stressing the importance. If like PI's or someone, would stress the people in the department it is important, take a step back. But if there are supervisors that drill their students to work 12 hours a day, then they are not going to do that. So it should also be a collaborative method in the workplace, that your boss or people remind each other that it is good to do this.

Interview 2

RRI

What does Responsible Research and Innovation mean for you?
"I think I have a vague idea, but I might be completely wrong." What you make affect humanity or the planet, like AI. How you do your experiments? How does it affect others? Like animal trials.

Do you feel comfortable with RRI? Why?
"I have the feeling that it is not that important for my research. Because I think my research is not that world changing." "The way I chose my project, I don't have to worry too much about that. There is not going to be probably a development that will make my research obsolete." "We are not that close to an application"

Do you feel responsible with one of the four dimensions? Which? Why (not)?
"We are very much on the foundational science." "There will be between what I finish and the first product coming out of it, there will be years of development for now."

Which of the four dimensions do you incorporate in your work? Why? Can you give some examples of this?
"I am a bit disconnected to all this. But it is not random, I chose my PhD project like that." I chose my project that would not include medical trials. "I have quite some strong opinions about what science should be allowed to do and what not. So I chose a project where I don't have these conflicts." "I wanted it like this."

Do you think reflexivity suit into your research?
"That's what most experimental scientist, or probably all of them have to do. I have to produce something and I have to think about how to do it. And actually most part of my projects was finding assays and that was the hardest part. And we noticed a lot of things were not working well or were not reproducible enough. So we had to adjust or completely change or find people to help us."
"I started the project as the first PhD students on this. So there was only the idea, but nobody had worked on this before."

Did you have problems in the start with that?
"In the beginning this was a bit scary. For the first half year I was not very focused in my research, I had to look around what to do. But then I came up with an idea and actually now we are writing the paper about that so that worked out quite well." "But I'm OK with that. That's science. It's not just doing what other people tell you, but coming up with your own ideas. In the end it is a lot of fun. You have to except the fact that a lot of work does not work."

Reflexivity

Do you feel responsible to be reflexive? Why?
"Yes, because science demands it of you. You have to sell your science. You have to think about why you are doing it to tell other people. Why you want money for it." "Scientists tend to make a lot of promises, which they can't keep in the end. And people lose a bit faith in science, which I try to avoid. But people don't like the answer: yeah we are doing foundational research. We are not trying to make something. People hate that answer because they don't understand what foundational research is.

"I feel responsible because I am also spending tax payer money. So it is not like I can do any kind of nonsense here. It has to work, it has to produce results."

Do you feel the need to be more reflexive in your work? And why? Do you see a difference in the first year or in the fourth year?
"In the first year, I just wanted to get it to work. To have a PhD project that actually worked. And then it was more about technical stuff and ideas to try. And now I am not at that point anymore. Because my main idea worked. Now it is more about getting it published." "Then you have to think a bit more about the context in general. About what does your work provide for science and society."

And you did not think about that in the first place?
Of course I had to give presentations to present my research. And saying oh this can be used in [redacted]. "The focus was more on getting something to present. And not so much on thinking what could be the larger effects."

Do you feel the need to be more reflexive in your work? And why?
As a scientists it is important to think about what we are doing and I think doing more and knowing more would be nice, but you have to invest time. It often involve reading books and learning about it and I have the feeling it is not happening too much in science in general. The prevailing way of working in science is like we need papers no matter the costs. There are some laws which forbids things like human experiments or on embryo's that are older than something. As long as there is no law, scientists are basically doing anything just to advance their careers, which I really dislike about science. And nobody ever stops to say we are not doing this because it is wrong or it would really have bad effects. You will always find someone who will ignore that. I think my research is not critical in that respect. I think my research will not make something dangerous to the world. I think it might make something useful or do nothing. So I don't think for me personally I have to think about my project so much, but I think about science in general.

I have the feeling that most scientists are very caught up in advancing their research and careers. There are just a few of them who say we should limit all research, because it can be very dangerous. It very sad and depressing at what stage science is at the moment.

Do you think these people need training for this? Or do you see this as a process?
I don't know if it is lack of knowledge, I don't think they lack training.

Reflexive training necessary?
It is really hard to say for me. I never had training like that. In my university this way really not the topic.

Would you have liked to have training like this?
I think it would have been interesting. I mean I read book about it. I think it would be an interesting topic for me and I think it is necessary. But I think it should happen during your studies. But I also think the way science works at the moment, it might not help very much. Funding does not go to people who say we are not doing it, it always goes to people who don't care.

Funding focused on RRI.
That would be a nice development.

What are the constraints of being reflexive within your research group or faculty?
I don't have in general the feeling that people are terribly reflexive. It is about getting results. By that is might be because my view of the BN department. So we are not really doing animal trials. There might be some areas of research, like [redacted] which might have a very big impact. But it is still very foundational. Because of this foundational research BN does not have to worry too much about it. And then it is not really discussed or done very much.

<u>Reflexivity tool or method</u>

What are your first thoughts about this?
"I think this will be hard to make people use if there is no pressure."
"It is very easy to ignore tools like that." "If there is no real feedback, people will just forget about it, in the daily deadline and everything."

Do you think such a tool or method could be helpful for being more reflexive in your daily work?
"I think so. Sometimes I think it could have been good to think a little more of what I am doing. Then I would have taken a slightly different direction or asked more people for help." "It's always easier to say afterwards."

[Statistics example]
"But maybe there were also just occasions like where the whole directions or experiments I decided to do, where not that useful in the end. What I might have foreseen. So I think it could be useful."

In what occasions would you like to use the tool/method?
"I think in the beginning of your PhD it is really useful. For example I started this new project, it might help to not get lost. Cause that happens in the beginning, if you don't continue a project, where everyone already have set up stuff for you and says you have to do this this and this. And I think for a lot of PhD projects this doesn't happen." Also helpful for students.

How often would you like to use the tool/method? And how long per time? It is more like, using the tool at the start of the project instead of using it monthly or weekly.
"I can imagine of using it more often. The start of the project is just the best example where it could be useful. But it would be good to come back also in interval."

What kind of intervals?
"Maybe 3 months. That's a period in which you can actually do something in research. Than you might have results."

Do you want to work with the tool/method alone? Or with colleagues?
"I think colleagues would be good. If it is just a computer program, the feedback is missing, because your computer program can't be smart enough to really give you much feedback. So definitely with other people.

Should the tool/method be something to do? Or something to think about (like a poster on the wall)?
"My experience is that I just ignore it after a wall, cause it is just part of the furniture. It should be something that reminds you automatically, like an email or something.

How do you think this tool should look like?
A tool just saying think about what you are doing will not be enough. It has to be more concrete. Maybe like a list of questions and maybe a way to compare your earlier answers to now. Or even like you see your earlier answers and first think about how it actually went. If you took it into account before you start with the next in the future.

"It should be as straight forward as possible. Because this would be something that people definitely would procrastinate, if it is not very concrete. If I can open the program and there is quite a concrete list of things to do I will probably do it. If I open a program, and there is one question and a giant text area to write something. I will probably procrastinate it and then not do it.

Further requirements tool/method. Method, like a game.
I personally don't like a game.
"I think interaction with other people is important." "Maybe with your PI or the other people who work very close to you."

Also with whole research group?
That's hard to say. Like in [redacted] group for example we have different fields which are not really connected that much. So the general direction of the group I would leave to the PI. But I think the smaller groups who work together on one topic, that would be something. To some extent we are doing this in our subgroup meeting. "If there was a more formalized way to do this. That might be useful."

Interview 3

RRI

What does Responsible Research and Innovation mean for you?

I guess it depends a lot on which area you look at. I guess you can look at responsible as ethical, ecological, safe for employees.

Do you feel comfortable with RRI? Why?

I think it is very important that we think about that, that we have those four. I think actually many researchers don't think about that all the time. "I do feel comfortable. It's not like I feel threatened."

Do you feel responsible with one of the four dimensions? Which? Why (not)?

I think I should do it, but I don't necessarily do it all the time. But I do think it's a great concept.

Especially one of the four dimensions?

"I was just thinking, anticipation is very hard for fundamental research. We tend to think about it a bit, because we have to sell the project. But in practice you have no idea where it might go. In ten years it might be totally gone or it might lead to something very interesting, we don't know yet."

Anticipation is indeed very difficult, also inclusion.

"Unless you would say inclusion as in other researchers that are looking at the same thing." "Because there is this tricking thing that there is also competition between researchers. So that doesn't always happen. If researchers like each other it happens."

Also within the TU Delft?

"Generally, within university it is fine, but as long as the people are not investigating exactly the same thing. Which rarely happens within the university, but there are exceptions." "But when they are actually very close, then I am not sure if they communicate that well to each other."

"I think reflexivity, that's the thing most scientists will do a lot, the whole time. On a small skill we have to think about our experiments every day and a bit further we have to think about papers, so we have to plan this. But I think it is very paper driven and publishable or not driven and not necessarily how can this impact society. But that may be linked also to the fundamental part, that we don't know anyway. Because honestly, I rarely think, oh, I should do that experiment because that would impact society better."

Reflexivity is not exactly on society, but more that you rethink thing up front. To prevent the experiments from being pointless.

"That I do really a lot. I think that will be the strongest of the four."

And do you think other PhD student also do that?

"I think so. If you become better at it. If you are more experienced, than you will do it more. I already noticed now of myself, that I do it now more than before, when I just started. Also because then people sometimes just tell you try this or try that, and just do it, but then you are not thinking about it as much as you should maybe."

Which of the four dimensions do you incorporate in your work? Why? Can you give some examples of this? Practical example.

"For example making [redacted]. Before people just said, you should do that, that would be so interesting. And you do it, and then, later on you realize, maybe that was not that useful and you spend quite some time on that. And now I take more time to think, do I really need to clone this or not?"

Reflexivity

Do you feel responsible to be reflexive? Why? Can you give examples of being reflexive in your work?

"Yes. 1. Because there is time limitation. You just become way more effective if you think about what you are doing, before you do it. 2. Because you want to create a nice story, that things are connected. To get a story, you need to think about it first and try to plan it." "And you get the best data, it looks cleaner. I had it before that I spend one day, it may feel like a waste of time when I am spending one whole day, I am preparing thing like making [redacted] perfectly, all the details. And then do the experiment the next day, then it looks better than it looks better than if I do it all on the same day."

Do you feel the need to be more reflexive in your work? And why?
"I think you can always improve on that."

Do you need training for this in first year? Or do you see this as a process?
"That for sure, you make mistakes and you learn from that. But it is also important of what kind of supervisor or team you have around you. If you have a supervisor that pushes you a lot, than you first need to learn that that might not be the best thing to do. [redacted]"

"[redacted]"

Will a training help?
"I don't think a whole course. Maybe just a few hours where people just really say, you know, this is a general thing. Because I've heard other people also saying that PI's will push you to do things, cause they want data and papers. But that it is not necessary the best thing and that you need to learn to really say, no, I am going to think about this. That you are more responsible of your own research." "Maybe that's something you also learn from talking more with others."

What are the constraints of being reflexive within your research group or faculty? Do you feel constrained?
"No, it is not that stimulated." "Sometimes I do feel constraint. One that people disturb you all the time, when you are thinking."
"[redacted] So I do feel somewhat constraint."

How do your colleagues think about being reflexive?
I know from some colleagues that they also feel quite similar. That they also sometimes need to have a day that they read more and think about it more. Cause we tend to go to the lab quite fast.

<u>Reflexivity tool or method</u>

What are your first thoughts about this?
Do you think such a tool or method could be helpful for being more reflexive in your daily work?
"I think it is a great initiative. The danger of these initiative is that when it becomes too complex, than people don't do it or they don't subscribe for it, because it takes too much effort. Because we are often pushed to work a lot. But I like the idea of it. Something that just popped up in my head, basically you reflect by people or something asking you questions. So if you would have a calendar that every day you take of a page. Maybe something like that. That you walk in your office and the question of the day is: do you really need to be at work today? Is the experiment you are going to do crucial? Have you thought of the experiment you are going to do? Nowadays apps are also, probably you also thought about apps."

Someone I interviewed before also said an app you be a good idea, but then you don't have the feedback. Do you think you should do it with more people? Or do you think it could also be useful yourself?
How I learned it so far, is indeed by talking to others. That would be an ideal way, especially within your research team. "To do that, you need trainings, or at least awareness of the PI's, so a level up. If you would have special meetings for that, people tend to not come to those things." "I think it will be hard to find a way to get people really together. But not saying that you shouldn't therefore."

In what occasions would you like to use the tool/method?
"I think it is some sort of habit you are trying to create, so it is not something necessarily need during your whole PhD." "I once read that habits they are fixed, you can call something a habit if you did it for two months. People train for marathons in the name of special apps and then that they achieve something. If you do something like that, that for two months you have a sort of schedule.

Like a gamification game?
Yeah, that could be something.

Other said a kind of mind map could be useful. So to step out of the details, and take a look at the global picture of your research. What do you think about somethings like that?
"It would be cool if you had some kind of poster in your lab or somewhere you see it a lot. That you are always reminded of this is the big pictures or this is the goal."

Should the tool/method be something to do? Or something to think about?
"I think it is very personal, these sort of things." Example given: trello, excel sheet.

Did you also feel like you were doing too few?
"It more that you think, time goes so fast and you are in your third year and you realize I don't have anything yet." "But I don't know if this would work for others, cause I can imagine some people want this mindmap, other people like trello."

All interviewees have different ideas on a tool. So it could be something personal, but we can probably also come up with something general.
"Yeah, or if just sharing these ideas. Because some other people might think, oh this excel thing is super lame, but other people might think, oh that's so simple, why didn't I think of that."

How often would you like to use the tool/method? And how long per time?
"The months-timescale is a bit long, because projects can just change very fast." "If you want to reflect more on individual experiments, then maybe more on the week scale." "It depends a bit on the goal, if you want to reflect more on specific experiments then I would say daily or whenever you do it. But for more the general lines, where are we going, should we do this or not, that's maybe a bit broader."

Would daily be feasible?
"If it is something fast, cause this excel thing I do daily."

Do you want to work with the tool/method alone? Or together?
I also have experiments with others, I have projects with two or with three.

Do you think such a tool could be incorporated into the organization?
"Yeah, I don't know logistically how you could do this right away."

Do you also think PI's would stimulate it?
"PI's are so different. If the TU delft would offer it and students would be happy to use it, they would be like, sure, use it, I don't care. As long as they don't have to pay for it. If they don't have the impression it slows people down, cause I think it would be tricky to market this. If you would market this, that people need to invest time for this. I wouldn't focus too much on this."
[redacted]
"The generally a bit more new generation PI's would be a fan, would support it."

Further requirements tool/method.
"I know you are thinking more like a tool now, but you could also do a "Reflexivity day" or something.

But will people go there?
"Then you have to make it a way like a Kavli day, that people have to go there."
Such a day could be the start, a kick-off day.
"Well it helps if you would organize it. You can use the kick-off day to also give the tool and people will come there to get the tool, as you sell it like, you get this amazing tool that was developed by TU Delft. And food."

Ambassadors/super-user
"Especially if you would have a PI that does something like this, it would be a stronger statement. Because they have already proven themselves as a scientist." "They might be better models. There are some PIs which are very popular. [redacted]"

Interview 4

RRI

What does Responsible Research and Innovation mean for you?
"I don't really know. Of course, the name is quite descriptive." It sounds like in principle every research that every person does, can have an impact for society or for a scientific community. If it impacts society or any kind of community you have to be responsible how your research impact. Does it goes in those lines?

Do you feel comfortable with RRI? Why?
"I have to confess that it is a lot to take. It is not something like, how you realize about that detail, you are talking about something that is really big. Especially the reflexivity, that is something that never ends. You have to always be questioning those things." "In the daily life I don't think about it. I have the feeling that if you want to cure malaria, for that you have to release a GMO to the wild. This impact is really clear, because it is very applied. It's gonna have an immediate impact on society and ecosystems. So it is obvious that you have to be thinking about these things. What I do, I see it more like a harmless thing to do. Right now we are very basic. Like a small scale in the lab, working more with concepts, more far from real world outside. So I kind of see myself a little bit far from that phase of being reflecting.

So you think RRI does not really apply to fundamental research?
I think it applies, but there are levels. The thing is that I don't see the responsibility. That responsibility is being challenged. [redacted] I am not working with human. I don't have to ask any consent to my molecules in the experiment. So I would say in our case in our lab, we are kind of safe in our small bubble that we have."

Do you feel responsible with one of the four dimensions? Which? Why (not)?
Anticipation: what is the scope? Next day of next 100 years? *The scope of the research (like 4 years).*
"In my case absolutely nothing is going to happen. My thesis is very basic, it's like you are writing a novel at home and you are not showing it to anybody. That book is never going to change, until you don't show it, nobody is going to read it. For my research to really have this kind of influence, we are really at the beginning. I cannot anticipate in my time being here that this is going to have any influence. At least not outside of this small bubble.
Reflexivity: "More projectwise". "I do think about it, why we are doing what we are doing. The most important part is that a grant was written and money was given for that. So if it is not because of that, I wouldn't be here doing that."

Why are you going in your direction?
"Because we think that is the most efficient way." "Yeah, sure, of course you have to think about it. That's obvious."

Smaller scale.
"Every day in the morning you have to decide what you are going to do and why you are doing that. But I don't know if that has something to do with this, cause those are scientific considerations or even technical consideration or even practical considerations."

But some people just do what their supervisor tell them.
"Of course this happens. You have to think about that. We are basically a team, we do it together. Although, obviously, I am the one who takes most of the decisions.

Inclusion: We have collaborators, e.g. [redacted] They are scientists. We have also connections with other labs. I think that part of what we do.

Responsiveness: Definitely. "It is an essential part of science. When you are young and are starting your PhD. Some people think you are going that way. In reality, it is always more stubborn, than PhD student or any person. And if something doesn't work, it is not going to work. And some day, you have to realize, this is not working, I have to do something else, cause it is not how I thought it was. And this happens 99% of the times."

Do you feel responsible with one of the four dimensions? Which? Why (not)?

"A little bit of everything" "If felt responsible for looking for collaborations. I did this actively myself, although nobody pushed me to do this."

Reflexivity

Do you feel responsible to be reflexive? Why?
"I think it is absolutely necessary. If you want to do a PhD you have to require that skill and that responsibility. No doubt."

Did you have it already in the start? Or need to learn?
"You need to have a certain level" "You never end developing that skill. You are constantly doing it and improving it. I think I have a lot, during my PhD and I still have a lot to go."

Can you give examples of being reflexive in your work?
"Just an example that I really learned recently." "One of the basics, is when you start a PhD, they tell you to start to write from the beginning. They never tell you how. To say: yes, start writing, I think is not enough. Cause you think, to write what? So in my opinion, to start to write means to have a strategy, to have a story that you want to tell in your research. Let's say you have a key message and you want to write a paper with that key message. That key message is going to give you the structure for everything. What experiments you are going to do and what you don't have to do and in what manner. That's something that I didn't do in the past, now I'm starting to do it. I think that is an example of that something I didn't do in the past, I reflect on it, I thought this is not good enough, together with [redacted] also discussing, we came to the conclusion that this thing had to be developed. I already did it, and I think this is impacting my research and improved it."

Do you feel the need to be more reflexive in your work? And why?
"Right now I think I am happier than before about my capacity to reflect about what I do and what I do in the way I do it. But definitely and as I said it is a process. If you asked me one year ago, I would have said, yeah, I have improved. But after one year I realized I have grown a lot from one year ago. Every step you take, you see how you were before and you think I have improved. But it is difficult to see sometimes from your current position, what's gonna be next. It is difficult to see forward. But as long as you have the correct attitude of: OK I think I am happy on how I am reflecting my research, but I think I can do more and I can do it better. You will always improve."

Do you need training for this? Or do you see this as a process?
In my opinion I think the most important thing is that you have a good direct relation with your supervisor. That you can really absorb knowledge and absorb the way your supervisor do things. Not only your supervisor, but also colleagues, more experienced scientific persons. The network is I think the key here. Because not everything is written, not everything is in a book, not everything is in a course. Of course, courses are very valuable, they are like concentrated pills of knowledge. Some are very good, others maybe not so much. To have this kind of knowledge will help a lot.

Training in reflexivity
"I wouldn't give a course with very abstract ideas. It has to be down to earth, down to exactly what people are doing. For example how to start writing from the beginning. Or strategy."

What are the constraints of being reflexive within your research group or faculty?
One thing is having constraints about being reflexive. All what I do is discussed with somebody else, in this case my supervisor. We are a team, we have to come together to an agreement to what we want to do. In my case, always discussed constraints are scientific ones.

I also mean reflexive in the sense of what am I doing? Are you allowed to do it?
I have time to think about it. Although it is true that there is a little bit of pushing towards going to the lab to do experiments. It depends on the period of time you are doing. For example there might be periods of time you need to reflect more. Maybe in those times there is a little bit of pushing to go to the lab to do experiments. In a sense this is also going to give you data. Maybe sometimes for some people it is hard to understand that I need to reflect. Although it is true that sometimes it is difficult to balance the time you take to think about it and you

are doing something. It is also important that you have someone that tells you, I think you are spending too much time on that.

Short: “The constraints that might be are trying to be balanced in a way. Sometimes I might feel to be pushed to the lab, maybe because I am taking too much time.”

How do your colleagues think about being reflexive?
“Definitely they value a lot to be reflexive. We all think that’s part of being a scientists. If you cannot reflect, you cannot be a scientist.”

Reflexivity tool or method

What are your first thoughts about this?
“I do agree, although I have to say that precisely in the beginning it is the most difficult part. I still don’t know so many things. At least now I have my criteria, I have the structure in my mind, so I can reflect on that. At the beginning you know nothing and you do mostly what your supervisor tells you and you don’t know so many thing. Which is something normal, I mean, first they have to push you a little bit, until you start moving by yourself. And that is not in contradiction with what I have said before.”

“My first thoughts is that it is a very nice thing to do, to improve on this. Because as I mentioned it is an essential part of being a scientist and being a good one.”

“During the whole interview I am starting to understand what you mean with responsibility. Because I have never heard of it and you were talking four dimensions, they are so abstract, that I don’t understand what you mean with them.”

“In the beginning you asked me responsibility. Responsibility for me sounds that you break something and you have to be responsible for it, you have to pay for it. But to be responsible in the sense of grown up, be mature, that’s definitely for sure, you have to do it and you have to train this. So my first thought is that it is very nice, that you want to do this. I think it is needed. The more we have this, the better, the better science we are going to do, the better scientists we are going to have.” “My second thought is that if you want to go for a tool or sth, in the end for me the most important part that is has to be with people, that is close to you, like colleagues, in your own departments. Like therapy groups, but it is not therapy, but it might be when people gather and present their own case, and the rest of the people can do exactly what those social scientists did. But the difference is, is that those colleagues of you are also really into it. And they can put you even more against your, you really have to make an effort to really know why you are doing that and that you can defend that in front of everybody else. Maybe you need to have a very broad audience, first with the most close related group of people, then you move to general scientists and then you move to general public, people who are not being a scientist. And that would be really hard to do, as this will be a lot of work, but all this spectrum might think is needed. You might be also to defend scientifically against your colleagues, but maybe there are things that are not thought of by your colleagues, because they are like you. And some layman person would say, why are you doing that? Because everybody is in the same small group and thinking in the same way. You have the same mindset.”

Do you think such a tool or method could be useful for being more reflexive in your daily work? On a small scale?
I think this would be the idea. Because you are forced to defend the details, then you have to every small detail can be different.

Now you are thinking about such a group meeting. Do you think this could also on your own?
“I see it in a way of a questionnaire. Where the science specifically to going to the most deep areas of your research even when not being specific. With exercises, thought exercises, imagine that you are somebody else, doing something completely different. And you have a competitor, you are your own competitor.” “This way you can reflect to yourself from the outside.” “Or exercises where you can actually write down the whole research that you are doing or strategy, and you can use flowcharts and everything.”

Mindmap. Get lost in the details. Step back.

"I was seeing something also similar. But I think in my opinion, the most important part is the people that you have surrounding you. That they are very well trained to really make you think about it. I have friends that are not even in this department that have done that with me. Three or four different times where I sat down for several hours with a friend. This friend started to make questions to me: why are you doing that? Why do you want to do that? In what way you will do that? What experiments you have to do? How long it is going to take you? Until you have nothing to say, but have a really good plan and to know why you are doing what you are doing."
"Maybe one idea, to catalyze this kind of discussions. Maybe a platform, maybe online, where strange people can get into contact with you and know a little what you are doing. Kind of like a tinder of research. So you have your own profile, and you can connect with people and can match with the people you think are interesting. It doesn't need to be in your same field, it can be in different fields. In this application for some time allows you to chat with that person. And you can ask questions like: Oh, what do you do, why do you do it in this way? And you do the same with the other person. And in this way you can while playing, in a sense knowing what other people are doing, what might be interesting, you can also put reflection under the person.

Also for other people than scientists?
The way I saw it, oh I want to know what other people are doing. First you have your profile: [redacted] and there are different categories. And other people can put their own settings to look for people like you. And they have this different people. And if they click on your profile and you also click on their profile. You have a chat, you can converse and you can ask questions about what others are doing. But for reflexivity it could be interesting.

Also university wise.
This could also facilitate collaboration for example and reflexivity.

In what occasions would you like to use the tool/method?
"As I mentioned, you are reflecting every day, every day about small things." "Every month you are reflecting about something bigger and every year about your PhD." "I think you have to be doing that always."

Should the tool/method be something to do? Or something to think about?
"No, something to do. I think that is a much better approach, because something to do means that you have to think about it. So you have to do both things."

Further requirements tool/method.
"Not really, it is better to be with people. Better if it is in person, face to face."

"And I think the most important thing is to have people trained on that and would understand how important is that. Not PhDs only, but also PIs trained on how to communicate those tools."

"People who have some kind of training, for example the PI, that can have this tool to be applied to his or her own group."

APPENDIX 4: CODE TREE DESIGN CRITERIA

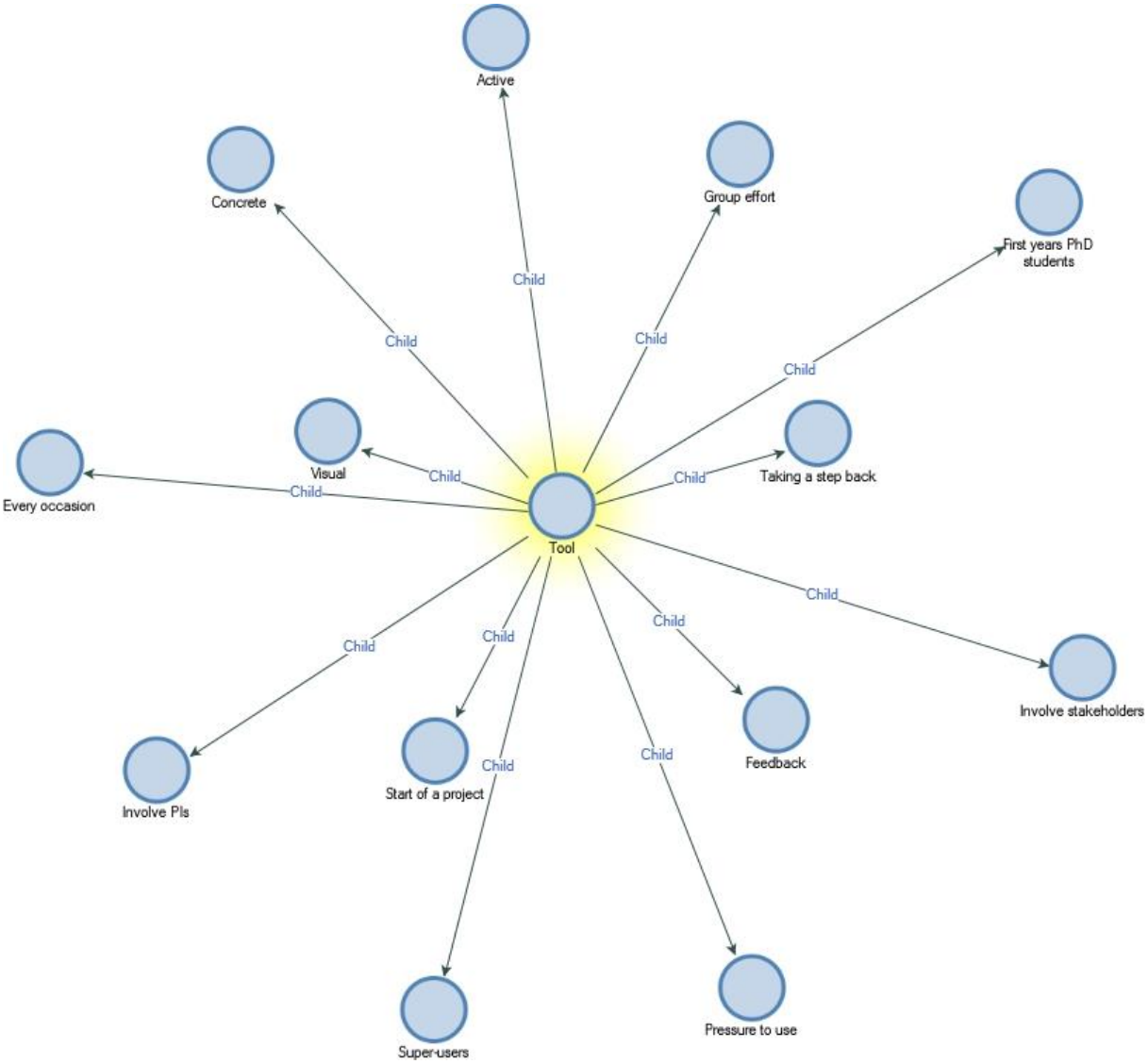


FIGURE 14: CODE TREE OF DESIGN CRITERIA FOR A TOOL TO STIMULATE REFLEXIVITY, OBTAINED FROM INTERVIEWS WITH FUNDAMENTAL SCIENTISTS.

APPENDIX 5. CODES & QUOTES

TABLE 9: QUOTES FROM THE SEMI-STRUCTURED INTERVIEWS BELONGING TO EACH CODE.

Code	Participant	Quote
Active	1	Program/app, where you can draw, not necessarily a mind map, but sort of like, what am I doing, what have I done. Like a one page.
	2	It should be something that reminds you automatically, like an email or something.
	4	Something to do. I think that is a much better approach, because something to do means that you have to think about it. So you have to do both things.
Concrete	2	It has to be more concrete
	2	It should be as straight forward as possible. Because this would be something that people definitely would procrastinate, if it is not very concrete. If I can open the program and there is quite a concrete list of things to do I will probably do it. If I open a program, and there is one question and a giant text area to write something. I will probably procrastinate it and then not do it.
	3	The danger of these initiative is that when it becomes too complex, than people don't do it or they don't subscribe for it, because it takes too much effort.
	4	I wouldn't give a course with very abstract ideas. It has to be down to earth, down to exactly what people are doing.
Every occasion	1	When things don't work or when you just finish or start a project. When you are to focused on the small thing and lose the bigger picture. Also when writing a paper.
	2	For example I started this new project, it might help to not get lost. Cause that happens in the beginning, if you don't continue a project, where everyone already have set up stuff for you and says you have to do this this and this. And I think for a lot of PhD projects this doesn't happen.
	2	I can imagine of using it more often. The start of the project is just the best example where it could be useful. But it would be good to come back also in interval.
	3	The months-timescale is a bit long, because projects can just change very fast. If you want to reflect more on individual experiments, then maybe more on the week scale.
	3	It depends a bit on the goal, if you want to reflect more on specific experiments then I would say daily or whenever you do it.
	4	As I mentioned, you are reflecting every day, every day about small things. Every month you are reflecting about something bigger and every year about your PhD. I think you have to be doing that always.
Feedback	2	I think colleagues would be good. If it is just a computer program, the feedback is missing, because your computer program can't be smart enough to really give you much feedback.
	2	Maybe like a list of questions and maybe a way to compare your earlier answers to now. Or even like you see your earlier answers and first think about how it actually went. If you took it into account before you start with the next in the future.

	4	And you have a competitor, you are your own competitor. This way you can reflect to yourself from the outside.
First year's PhD students	1	I think I am much more reflexive now than I was three years ago.
	1	And especially you can also see this difference between people who are in fourth year or people who are in first year.
	1	It is also when you are starting in your first year you think you are going to change the world. And then you realize it is not like that.
	2	I think in the beginning of your PhD it is really useful.
	3	I already noticed now of myself, that I do it [reflecting] now more than before, when I just started.
	4	Right now I think I am happier than before about my capacity to reflect about what I do and what I do in the way I do it. But definitely and as I said it is a process. If you asked me one year ago, I would have said, yeah, I have improved. But after one year I realized I have grown a lot from one year ago. Every step you take, you see how you were before and you think I have improved. But it is difficult to see sometimes from your current position, what's gonna be next. It is difficult to see forward. But as long as you have the correct attitude of: OK I think I am happy on how I am reflecting my research, but I think I can do more and I can do it better. You will always improve.
Group effort	1	It kind of trains you indirectly to look at it from different views.
	1	So it should also be a collaborative method in the workplace, that your boss or people remind each other that it is good to do this.
	2	I think colleagues would be good. If it is just a computer program, the feedback is missing, because your computer program can't be smart enough to really give you much feedback. So definitely with other people.
	2	I think interaction with other people is important. Maybe with your PI or the other people who work very close to you.
	3	How I learned it so far, is indeed by talking to others. That would be an ideal way, especially within your research team.
	3	I also have experiments with others, I have projects with two or with three.
	4	Not only your supervisor, but also collegues, more experienced scientific persons. The network is I think the key here.
	4	My second thought is that if you want to go for a tool or sth, in the end for me the most important part that is has to be with people, that is close to you, like collegues, in your own departments. Like therapy groups
Involve PIs	1	If like PI's or someone, would stress the people in the department it is important, take a step back.
	2	I think interaction with other people is important. Maybe with your PI or the other people who work very close to you.
	3	To do that, you need trainings, or at least awareness of the PI's, so a level up. If you would have special meetings for that, people tend to not come to those things.
	3	Especially if you would have a PI that does something like this, it would be a stronger statement. Because they have already proven themselves as a scientist.

	4	In my opinion I think the most important thing is that you have a good direct relation with your supervisor.
	4	And I think the most important thing is to have people trained on that and would understand how important is that. Not PhDs only, but also PIs trained on how to communicate those tools.
Involve stakeholders	4	Maybe you need to have a very broad audience, first with the most close related group of people, then you move to general scientists and then you move to general public, people who are not being a scientist.
Pressure to use	2	I think this will be hard to make people use if there is no pressure.
	3	Then you have to make it a way like a Kavli day, that people have to go there.
	3	If you would have special meetings for that, people tend to not come to those things.
Start of a project	1	When things don't work or when you just finish or start a project.
	2	For example I started this new project, it might help to not get lost.
Super-users	3	They might be better models. There are some PIs which are very popular. I think Bertus.
	4	But I think in my opinion, the most important part is the people that you have surrounding you. That they are very well trained to really make you think about it.
	4	And I think the most important thing is to have people trained on that and would understand how important is that. Not PhDs only, but also PIs trained on how to communicate those tools.
Taking a step back	1	I think for PhD students it might be useful, cause we a lot of the times just tend to get lost in the details and really get stressed out and lose the bigger picture.
	1	If it does not work according to your hypothesis and you feel sad, but then you know you need to take a step back
	3	That you are always reminded of this is the big pictures or this is the goal.
Visual	1	Especially visual. As you can always go back to it.

APPENDIX 6. PROTOCOL CO-DESIGN SESSION

PLAN SESSION MORPHOLOGICAL CHART

Materials:

- Morphological chart bike as example – A3
- Morphological chart – A0
- How to – A3
- Concept forms – A4
- Weighted criteria forms – A5
- Parking lot – A4
- Tape
- Sticky notes
- Coloured sticker dots (64 dots per colour)
- Pens
- Markers
- Photo camera
- Cookies and drinks

Methods:

Part 1: Introduction & warming-up (10 minutes)

Today, we will define a concept of the tool, method or activity. I will guide the session, Mariska studied industrial design and just graduated and will help with her design knowledge and you are the users or experts on the topic. Let's do an introduction round, although I think you guys already know each other.

As an icebreaker, to get a bit more creative, we will do a game called 'pinkelen'. I will first be the commander and if I say commando in front of an action you have to do the action. If I don't say commando in front of the action you should not do it. The actions are 'pinkelen', 'cup', 'cone'. If you are doing it wrong, you have to take over the lead.

Now we warmed up, lets repeat what is reflexivity. Reflexivity means reflecting on your activities or **self-awareness** by for example rethinking prevailing conceptions. You can think of asking yourself what are you doing, why you are doing something, thinking of alternatives and what outcome that would have. This could be done midstream, which means during the research (not before or after). And for this I would like to create a tool/method/activity to stimulate reflexivity of fundamental scientists. For now, I will use the term concept for the end product, which could be a tool, an activity or a method. Do you all understand?

Part 2: How to? (50 minutes)

When analysing the interviews I formulated a list of design criteria for the tool. Besides, criteria for reflexivity were found in literature. This merged these criteria into a list of 16 design criteria. These will be used as a guidance for the design process. Coming up with a concept will be done by using a morphological chart. The design criteria are sorted on priority. The upper most (in dark green) were

mentioned by four of the four interviewees and the lighter green it gets the fewer it was mentioned. The last four design wishes are reflexivity related from literature.

The solutions are the answer to the question “How to?”. Before filling in the chart we will answer these questions

Each of you will get a form with a ‘how to’ question. You have 3 minutes to fill in the solutions on post-its. One solution per post-it. After three minutes, your form can be shifted to your neighbour and this will be repeated until everyone saw every form.

If concepts are thought of during this sessions, these can be placed on the parking lot. When we will start with the concepts part, we will take these ideas also into account.

Part 3: Hits & dots (10 minutes)

Everyone will get three coloured dots. On every ‘How to?’ form three dots can be placed on the post-its, a green one, a blue one and a yellow one. The green one you stick on your favourite solution, the blue one on the most innovative solution and the yellow one on the most feasible solution. All post-its with stickers on them will be gathered and placed on the morphological chart.

[Apply SCAMPER: Can we substitute, combine, adapt, modify, put to another use, eliminate, or reverse the ideas?]

BREAK WITH DRINKS AND COOKIES (10 minutes)

Part 4: Formulating concepts (30 minutes)

A concept (tool/method/activity) can be formed by combining the solutions. For making the concepts, not every criteria has to be taken into consideration. So look at the morphological chart and start making concepts. Don’t forget to take the parked concepts into account. You have 30 minutes to do this. You can work together or do it alone. Please discuss your concepts to prevent doing double work.

Part 5: Weighted criteria (10 minutes)

Several concepts are formulated and we will evaluate them on several requirements. These are general requirements involving my research question and the feasibility. Before evaluating the concepts, the weight of each criteria should be defined. That is what we are going to do now. You can divide 100 points over these six requirements. We are going to do this as a group, so you should come to a compromise.

After this, Mariska and I will rank the concepts and choose the best one or a combination of two. This concept I will work out further and will test it with another group of PhD students.

Part 6: Closing remarks (5 minutes)

I would like to hear from you what you thought about this. Do you have any comments or remarks?

APPENDIX 7: HOW TO?-FORMS

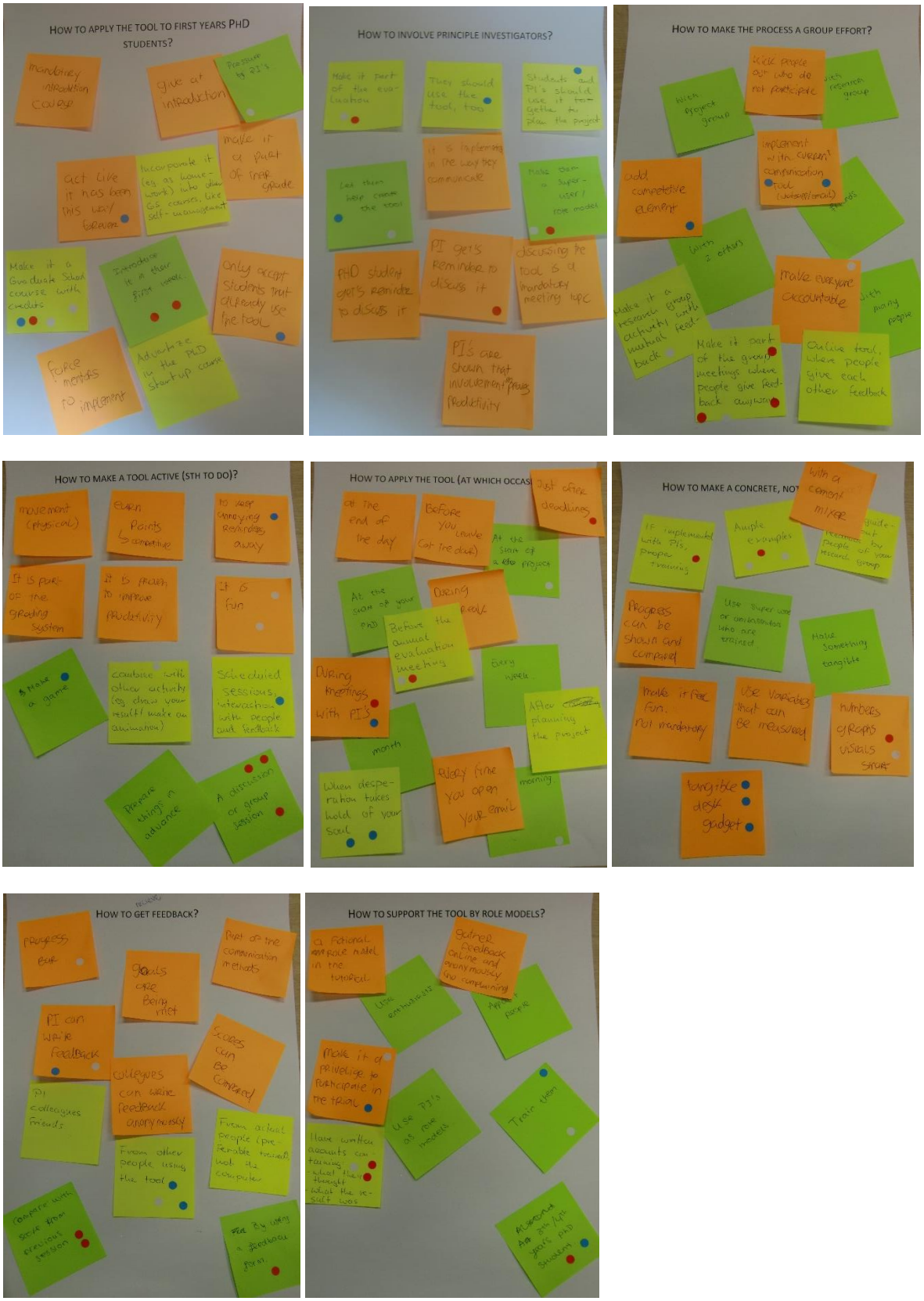


FIGURE 15: EIGHT OF THE SIXTEEN "HOW TO?" FORM USED DURING THE CO-DESIGN SESSION INCLUDING POST-ITS WITH SOLUTIONS TO THE H2-QUESTION.

FIGURE 16: EIGHT OF THE SIXTEEN "HOW TO?" FORM USED DURING THE CO-DESIGN SESSION INCLUDING POST-ITS WITH SOLUTIONS TO THE H2-QUESTION.

APPENDIX 8: CONCEPT FORMS

FIGURE 17: NINE OF THE SIXTEEN FILLED IN CONCEPT FORMS FROM THE CO-DESIGN SESSION AND THE MEETING WITH OTHER SCIENTISTS AFTERWARDS.

FIGURE 18: SEVEN OF THE SIXTEEN FILLED IN CONCEPT FORMS FROM THE CO-DESIGN SESSION AND THE MEETING WITH OTHER SCIENTISTS AFTERWARDS.

APPENDIX 9. MIRROR TOOL – FIRST VERSION

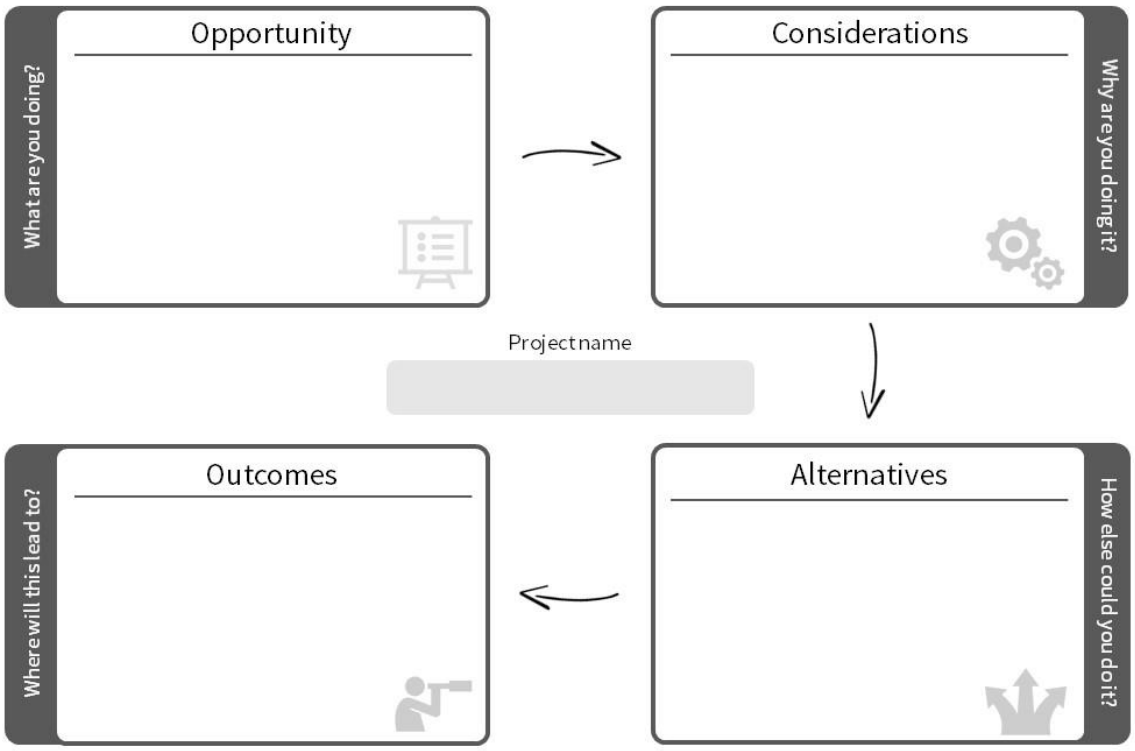


FIGURE 19: FIRST VERSION OF THE MIRROR FORM.

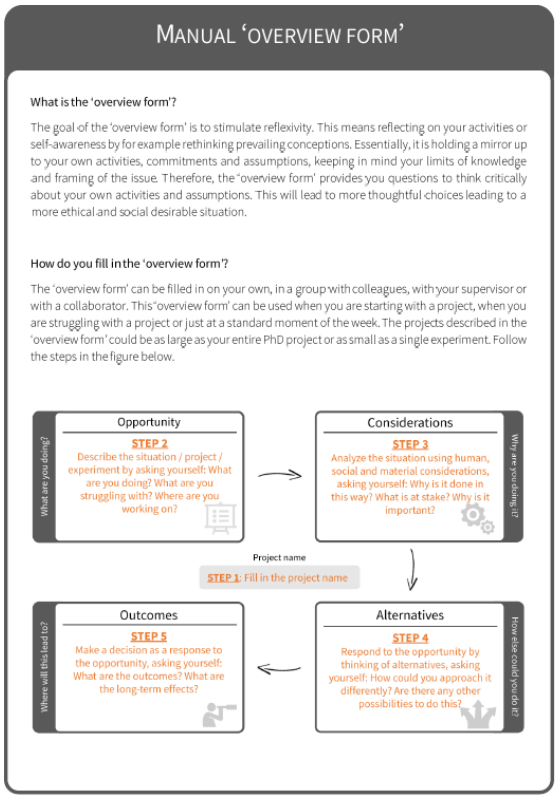


FIGURE 20: FIRST VERSION OF THE MANUAL OF THE MIRROR TOOL.

APPENDIX 10. MIRROR TOOL – TEST VERSION

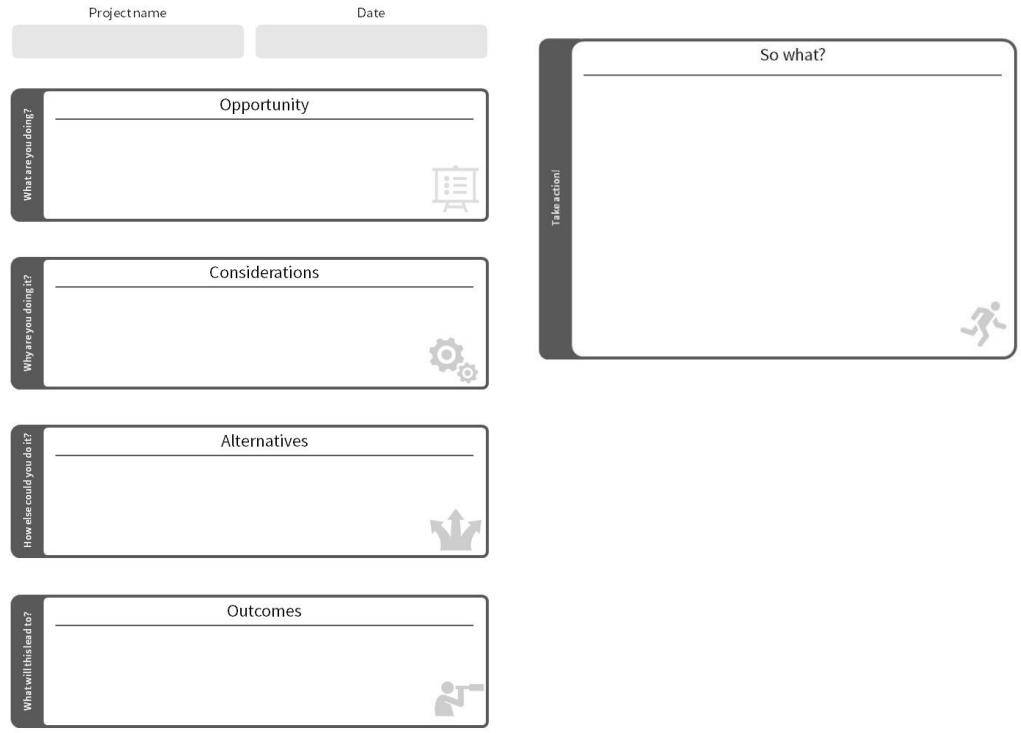
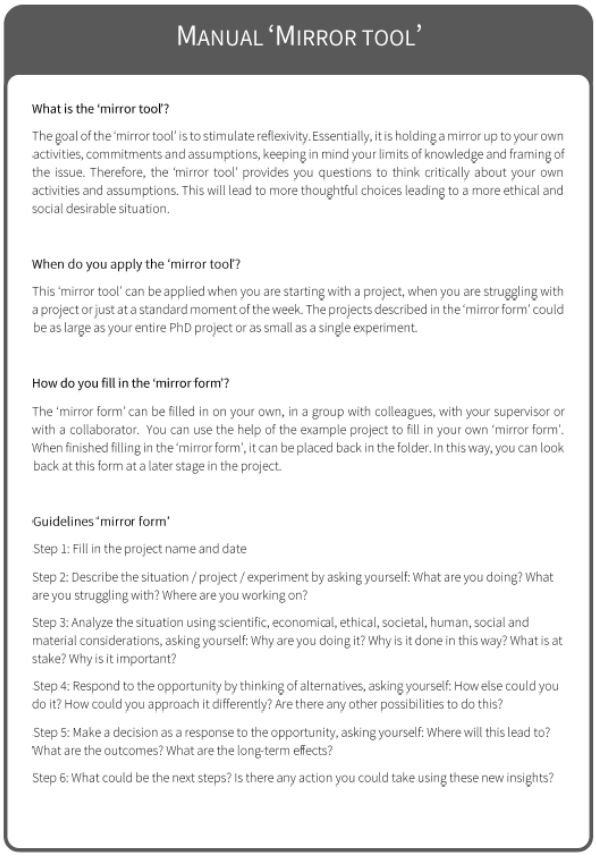


FIGURE 21: FRONT AND BACK PAGE OF THE MIRROR FORM USED DURING THE TEST SESSION.



MANUAL 'MIRROR TOOL'

What is the 'mirror tool'?

The goal of the 'mirror tool' is to stimulate reflexivity. Essentially, it is holding a mirror up to your own activities, commitments and assumptions, keeping in mind your limits of knowledge and framing of the issue. Therefore, the 'mirror tool' provides you questions to think critically about your own activities and assumptions. This will lead to more thoughtful choices leading to a more ethical and social desirable situation.

When do you apply the 'mirror tool'?

This 'mirror tool' can be applied when you are starting with a project, when you are struggling with a project or just at a standard moment of the week. The projects described in the 'mirror form' could be as large as your entire PhD project or as small as a single experiment.

How do you fill in the 'mirror form'?

The 'mirror form' can be filled in on your own, in a group with colleagues, with your supervisor or with a collaborator. You can use the help of the example project to fill in your own 'mirror form'. When finished filling in the 'mirror form', it can be placed back in the folder. In this way, you can look back at this form at a later stage in the project.

Guidelines 'mirror form'

Step 1: Fill in the project name and date

Step 2: Describe the situation / project / experiment by asking yourself: What are you doing? What are you struggling with? Where are you working on?

Step 3: Analyze the situation using scientific, economical, ethical, societal, human, social and material considerations, asking yourself: Why are you doing it? Why is it done in this way? What is at stake? Why is it important?

Step 4: Respond to the opportunity by thinking of alternatives, asking yourself: How else could you do it? How could you approach it differently? Are there any other possibilities to do this?

Step 5: Make a decision as a response to the opportunity, asking yourself: Where will this lead to? What are the outcomes? What are the long-term effects?

Step 6: What could be the next steps? Is there any action you could take using these new insights?

FIGURE 22: MANUAL OF THE MIRROR TOOL USED DURING THE TEST SESSION.

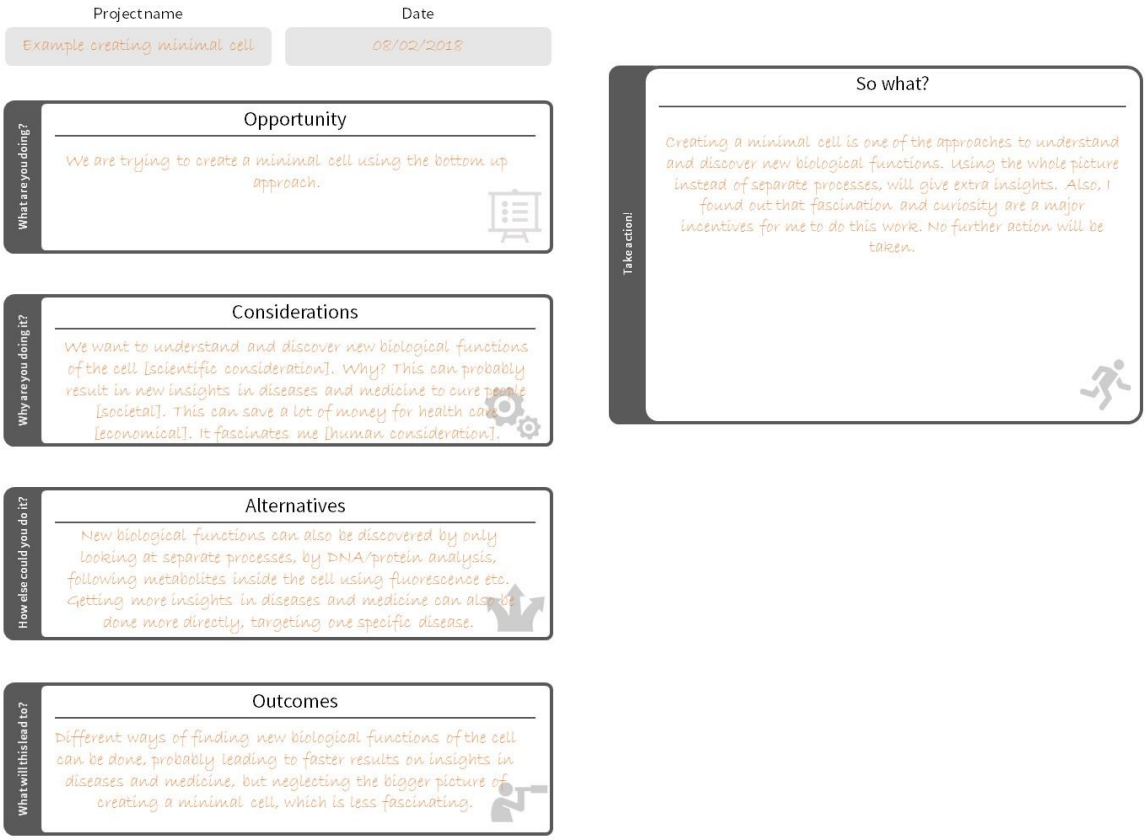


FIGURE 23: FRONT AND BACK PAGE OF EXAMPLE FORM 1 USED DURING THE TEST SESSION.

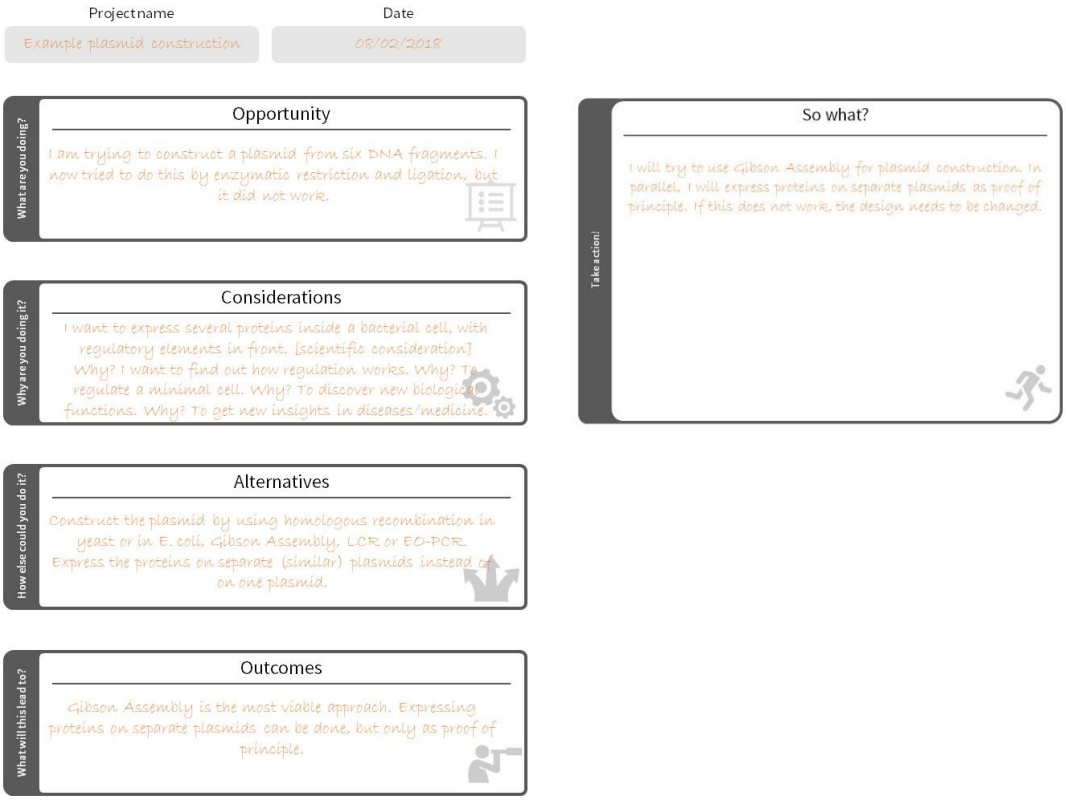


FIGURE 24: FRONT AND BACK PAGE OF EXAMPLE FORM 2 USED DURING THE TEST SESSION.

APPENDIX 11. MIRROR TOOL - FINAL VERSION

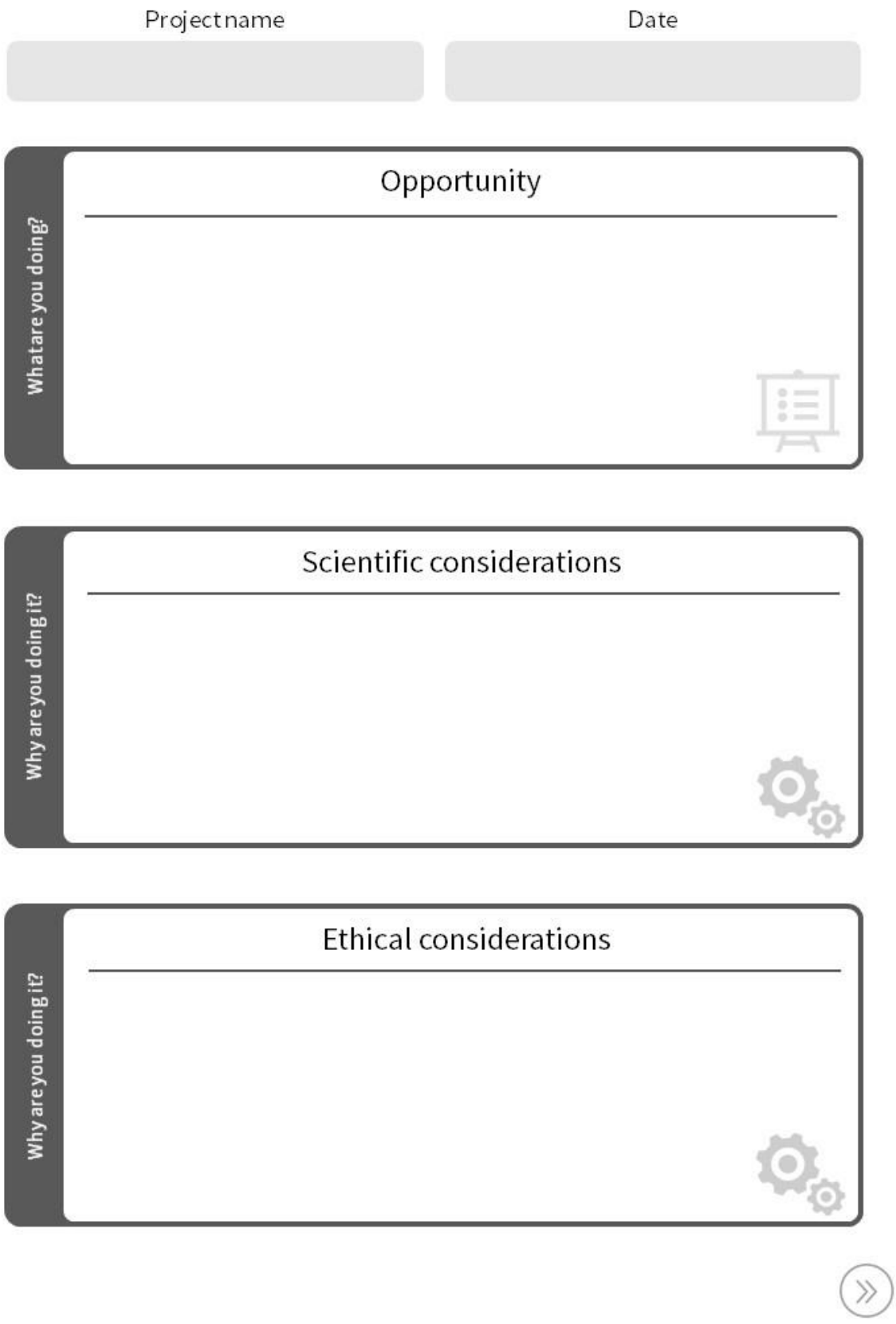


FIGURE 25: FRONT PAGE OF THE FINAL VERSION OF THE MIRROR FORM. THIS FORM IS DESIGNED TO STIMULATE REFLEXIVITY OF FUNDAMENTAL SCIENTISTS.

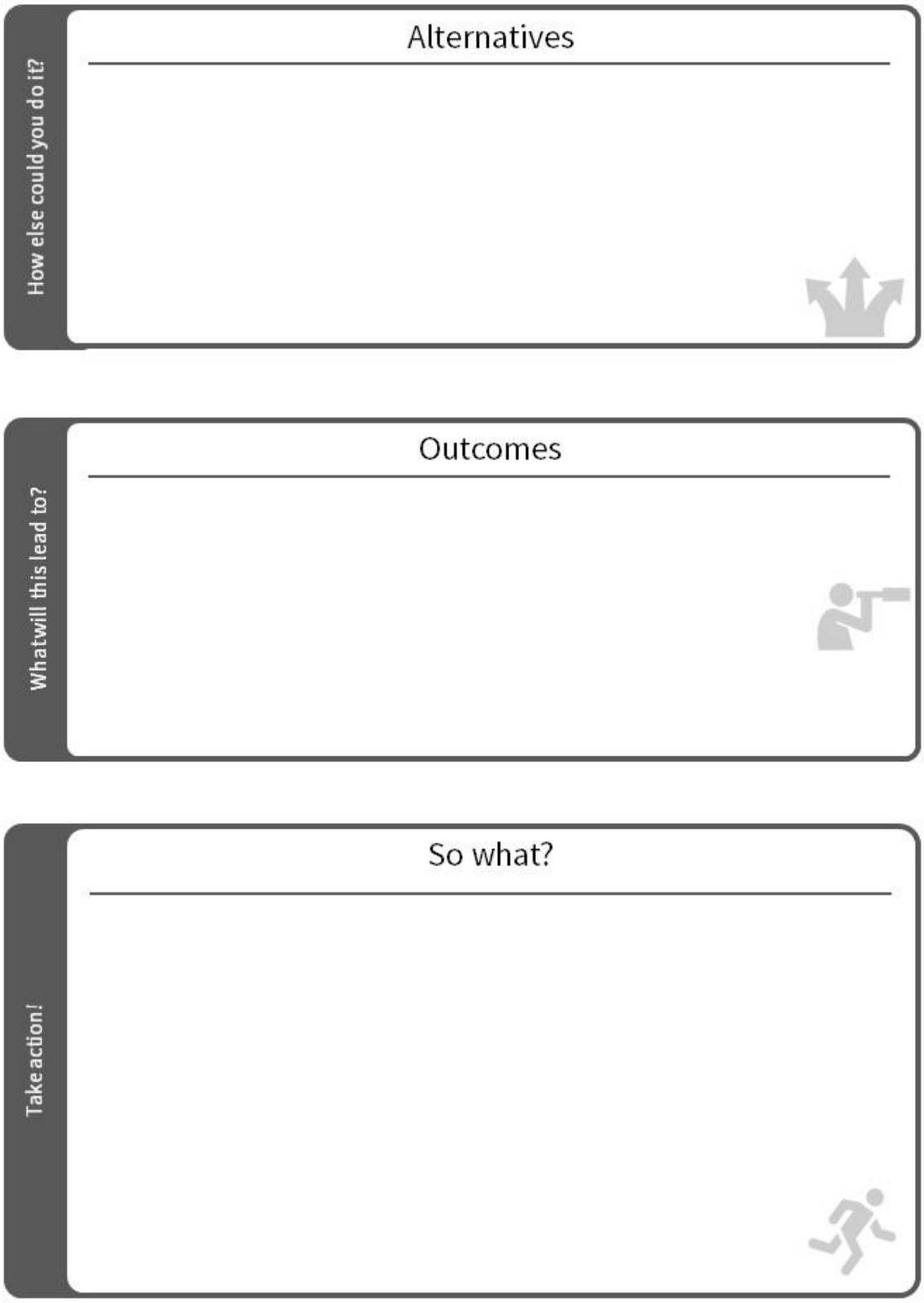


FIGURE 26: BACK PAGE OF THE FINAL VERSION OF THE MIRROR FORM. THIS FORM IS DESIGNED TO STIMULATE REFLEXIVITY OF FUNDAMENTAL SCIENTISTS.

MANUAL 'MIRROR TOOL'

What is the 'mirror tool'?

The goal of the 'mirror tool' is to stimulate reflexivity. Essentially, it is holding a mirror up to your own activities, commitments and assumptions, keeping in mind your limits of knowledge and framing of the issue. Therefore, the 'mirror tool' provides you questions to think critically about your own activities and assumptions. This will result in more thoughtful choices leading to a more ethical and social desirable situation.

When do you apply the 'mirror tool'?

This 'mirror tool' can be applied when you are starting with a project or when you are struggling with a current project. The projects described in the 'mirror form' could be as large as your entire PhD project or as small as a single experiment.

How do you fill in the 'mirror form'?

The 'mirror form' can be filled in on your own for an individual project or in a group with colleagues for a group project to verbalize your thoughts.

You can use the help of the example forms to fill in your own 'mirror form'. When finished filling in the 'mirror form', it can be placed back in the folder. In this way you can look back at this form at a later stage in the project.

Guidelines 'mirror form'

Step 1: Fill in the project name and date.

Step 2: Describe the problem / situation / project / experiment by asking yourself: What are you doing? What are you struggling with? Where are you working on? (Not why, see next step)

Step 3: Analyze the situation using considerations, asking yourself: Why are you doing it? Why is it done in this way? What is at stake? Why is it important?

Step 4: Analyze the situation using ethical, economical, societal, human, social and material considerations, asking yourself: Why are you doing it? Why is it done in this way? What is at stake? Why is it important?

Step 5: Respond to the opportunity by thinking of alternatives, asking yourself: How else could you do it? How could you approach it differently? Are there any other possibilities to do this?

Step 6: Make a decision as a response to the opportunity, asking yourself: Where will these alternatives lead to? What are the outcomes of these alternatives? What are the long-term effects?

Step 7: What could be the next steps? Is there any action you could take using these new insights?

FIGURE 27: MANUAL OF THE FINAL VERSION OF THE MIRROR TOOL.

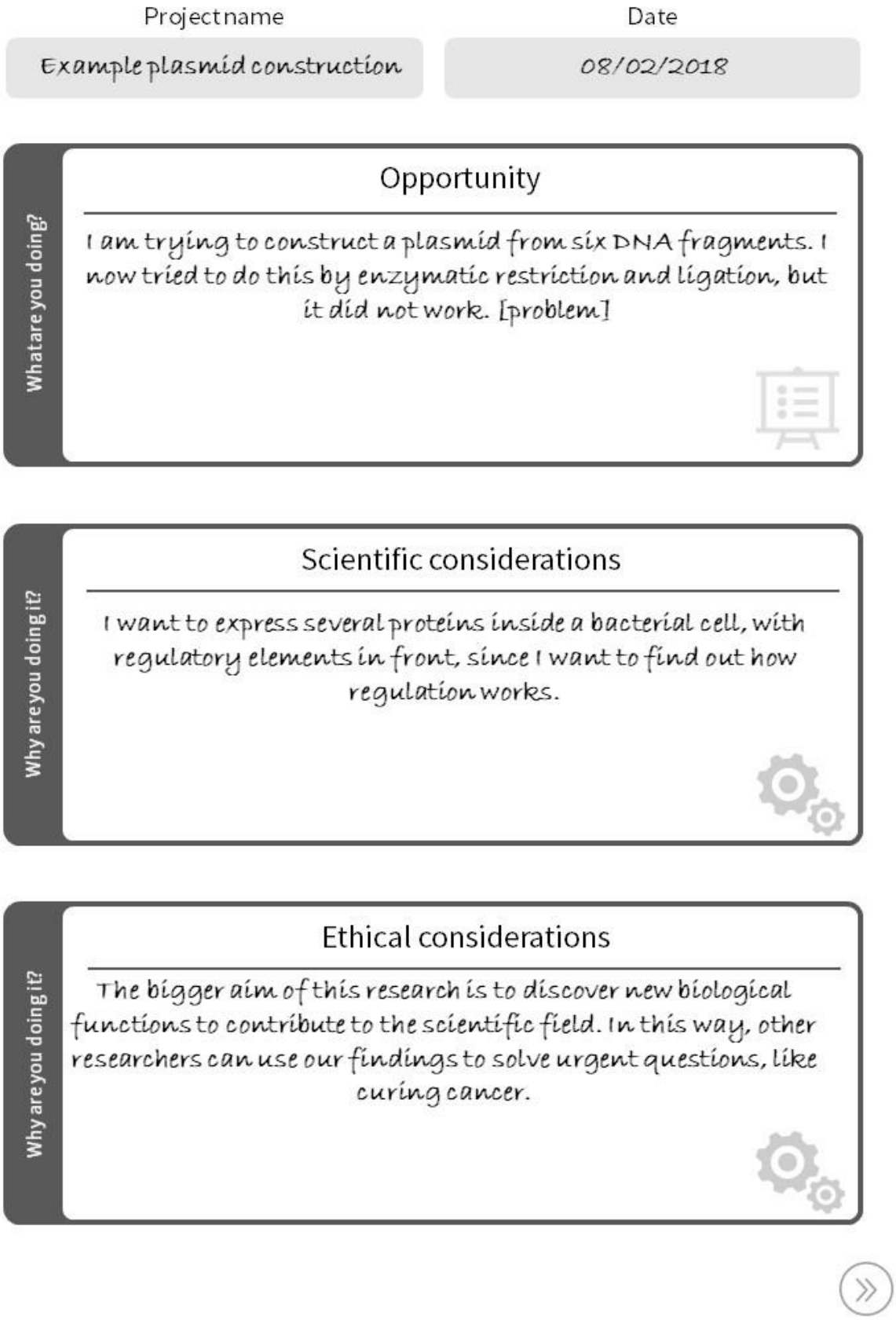


FIGURE 28: FRONT PAGE OF THE FINAL VERSION OF EXAMPLE MIRROR FORM 1 .

How else could you do it?

Alternatives

Construct the plasmid by using homologous recombination in yeast or in E. coli, Gibson Assembly, LCR or EO-PCR.
Express the proteins on separate (similar) plasmids instead of on one plasmid.

What will this lead to?

Outcomes

For homologous recombination in yeast, a new ori and marker and homologous flanks are necessary. For Gibson Assembly, LCR, and EO-PCR homologous flanks are needed. GA is the most viable approach.
Expressing proteins on separate plasmids can be done, but only as proof of principle.

Take action!

So what?

I will try to use Gibson Assembly for plasmid construction, as this is the most viable approach. In parallel, I will express proteins on separate plasmids as proof of principle. If this does not work, the design needs to be changed.

FIGURE 29: BACK PAGE OF THE FINAL VERSION OF EXAMPLE MIRROR FORM 1.

FIGURE 30: FRONT PAGE OF THE FINAL VERSION OF EXAMPLE MIRROR FORM 2.

FIGURE 31: BACK PAGE OF THE FINAL VERSION OF EXAMPLE MIRROR FORM 2.

APPENDIX 12. PROTOCOL TEST SESSION

Materials:

- Folder including mirror forms, example form and manual
- Interview protocol
- Pens
- Recorder
- Cookies

Methods:

Introduction

Welcome everybody! Thanks for coming. In the coming half an hour you will be using the tool I created during my graduation project and afterwards you will be interviewed on your experiences. Before this, I did interviews with other PhD students and together with them and a designer we came up with many concepts. Based on five essential criteria, I chose the 'mirror tool' to be the most feasible, useful, implementable and reflective solution. For now, I won't give you more information to not influence.

Testing the tool

I will now hand over this folder including the 'mirror forms', an example form and the manual. Try to read the manual and afterwards fill in three 'mirror forms'. As you will read in the manual, these projects could be as large as your entire PhD project or as small as a single experiment.

Group interview

Follow the interview protocol. Make sure all participants take charge in the interview.

APPENDIX 13. INTERVIEW PROTOCOL TEST SESSION

Introduction

Now, I would like to interview you on the tool you just used. I would like to record the interview if that is okay by you. This recording will only be used for educational reasons, and the recording nor the information you give to me will be spread. First I will ask you all to give your global impression of the tool.

Global impression

First of all, what did you think of the tool?
What did you like about the tool? What not?
In what way could this tool help you?

Reflexivity

This tool is intended to stimulate reflexivity. Reflexivity is essentially holding a mirror up to one's own activities, commitments and assumptions, keeping in mind your limits of knowledge and framing of the issue.

To what extent does this tool increase your reflexivity? And why? (If necessary, on a scale from 1 to 5, with 1 for no increase and 5 for extreme increase)
To what extent did the tool take you a step back to view the bigger picture?
To what extent did the tool help you to take socio-ethical and socio-economic aspects into account?
To what extent did the tool facilitate a systematic and disciplined way of thinking?
How did you experience filling in de mirror form? Did you feel free to be open, make errors and not being judged?

What part of the tool would you consider as useful?
What would you change?
What do you think about the questions asked?
What do you think about the last step? This step is actually not in the scope of my project, since it is not about reflexivity, but about responsiveness. *Do you think this step is necessary? Why?*

What do you think about the manual? Is the use of the tool clear? Did you get enough information to fill in the tool? Which instructions would you add?

In what occasions would you like to use the tool/method?
How often would you like to use the tool/method? And how long per time?
With who would you use the tool? Or alone?
Why would you use the tool?

Do you have suggestions for improving the tool?
Can you think of any add-on to the tool?
Would you use the tool if it is available?

Closing
Further suggestions?
One last question, what do you think of the name of the tool "mirror tool"?
Thank you very much for your time and participation as a test panel of my tool.

APPENDIX 14. TRANSCRIPT GROUP INTERVIEW TEST

I = interviewer, P1 = participant 1, P2 = participant 2, P3 = participant 3, P4 = participant 4.

Participants 3 and 4 are first year's PhD students.

I: What did you think about the tool?

P2: I think it can be useful, it depends a bit on the situation you are in, so I think it depends on if you have stuff that you really basically haven't thought through yet.

P3: I agree, so I think also when you are sort of stuck, then this might be a nice structured way to think back. I guess especially the question why are you doing it this way. That is especially practical.

P1: I don't really have problems, you call it opportunity or the way you want, but you need a problem to start with. So if you don't really have any. For me it was really hard to fill something it in. Why do you do it? Because I decided to do it that way.

P4: For me it seems a little bit too early to fill in something like that, because I am still trying to figure out where the project is about. Might be a little bit later helpful.

I: What did you like about it?

P4: What else could you do? I think that is the most brainstorming part.

P2: I think that is well to really visualize the alternative for yourself. So well, ok, if I would not do it, than actually what would happen? I think that is the useful part of the form. Because that's sometimes when you do, you don't really think through. Oh, I have to do that, what will happen if I don't do it?.

I: You said, it could help you at the start of a project or when you are stuck. Is it also better for first year's students or older years?

P3: Well, I don't think it is necessarily better for first year's students only in the sense that maybe later on you will learn yourself just a kind of structure. So in that sense.

I: So you two (P1 and P2) are doing your PhD a bit longer. Do you think you can already do this yourself without such a form? or it is still useful?

P2: I think it depends on the situation. So I think normally I kind of do that in my head. But I don't think this is necessarily depending on if you are first or third years student. I think this can be nice for first year's and third years student. Maybe for first year's student it might me more likely you have not developed this kind of technique.

P1: I think it more depends on the stage of the project, because if you are like finishing a project or everything is set to go, and you just have a list of experiments that you work out, then it is not useful. But in the part where you are still thinking about how should I do it. At that point it would be really good to evaluate, but what if I do it in any other way, to see what you chose is really the best way. And that can be of course in the first year at the start, but also in you third year.

I: So it is probably easy to introduce it at the first year's, but they don't really need it right there. But they can probably use it later on.

P4: But I think, for the first year, what will this lead to, is a bit too early. Cause you have so many possibilities how projects may continue. The project might change the flow in any direction.

P1: But that is still true for a third year project. It might be as well, it depends on how things go. So I don't think that is a first year thing. And you have to do this all the time, basically, these kind of decisions.

P3: But I think that maybe in the beginning you do it more automatically to look at all the different options and then just choose one. But I think when everything goes well, then you might not need it. But when you get in trouble and things are not working as you would expect. And then you sort of become focused on one part, like the path that you chose. And you don't reconsider the other option anymore. Then maybe it is nice to go back all the way. Maybe in that sense.

I: And of course this tool was to stimulate reflexivity. To what extent does this tool increase your reflexivity and why?

P1: I think I am usually quite reflexive. I do not necessarily need this form to go through all these steps.

P2: Me too, I think I indulge already enough self-reflection, so I would not feel it necessary for me.

P4: For me, I am ok when I do like small projects or small experiments. But if I try to think about the global outcome of the project. Then I think it might be helpful to see and to write down and try to understand how it helps and not help. So more for the global projects.

P3: I agree, so I think indeed for the, especially in the beginning because you have so many option now, then it is a little bit, you have to reflect on what you want to do. And indeed for the bigger picture that might be good.

P1: I think if you really want to use it for the big picture. The format, there is so little space to write. Now I also had little time of course. If I would really do this for my whole project I would need to spend a day and write pages and pages maybe. because now, if I have these frameworks I feel super limited in what I can write and that already limits everything I am thinking.

P3: But as a start maybe.

I: It could also be a computer program where you can extent with unlimited space.

All: Yes.

I: To what extent did the tool take you a step back to view the bigger picture?

P3: Because it is for different projects right, for a big and smaller project. For the bigger project, it did take you a step back. Because, now I am working on a smaller component to make that work first and it takes you back again.

P1: Just rewriting the steps you discarded long ago as stupid and it really takes you back. And that is maybe good to sometimes rethink.

I: To what extent did the tool help you to take the social-ethical and socio-economical aspects into account?

P1: I didn't have space for that

P2: Somewhat a bit..

P3: I think, because it is still quite far away, the socio-economical aspects, I think it is not a big part of the work.

P4: But basically in any of our case. We have quite a variety of projects and if you want, for almost all of them, you can link to cancer diseases. For all like fundamental science you can escape to the transitional medicine. We always do fundamental, but if you really want you can always write a paragraph, like it is also important for cancer.

P3: If you really think long about it, you can write a lot.

I: To what extent did this tool facilitate a systematic and disciplined way of thinking?

P1: By asking the questions in this order, it already gives some kind of structure. Which is logical, but it nice to reforce that I guess. Otherwise you may get always around and forget steps and get lost in your own thoughts maybe.

P2: I just agree with that.

P3: I think the 'how else could you do it?' Is the most powerful maybe. I thought sometime the 'why are you doing it?' you can interpret depending on which skill you are looking. You can sort of interpret it in different ways. Because you have different layer, you start sort of small and you can go to the bigger picture. But 'how else could you do it?' that really reflects on why you chose what you chose to do.

P1: I sometimes had a bit of trouble when I was writing the opportunity. It feels so logical to explain you are doing something to do this. And then you are already at the considerations part. So when I read what are you doing. Well, it is good to keep them separate. It could be forced to keep them more separate, I don't know how.

I: How did you experience filling in the form? Did you feel open? And allowed to make errors? And not to be judged?

P1: I felt judged by you, haha.

P2: Well I can't say how I would fill it in in a group. But for myself alone, I can just focus on it.

P4: Maybe alone I could spend more time. If I have like more time and take it like a task in project development, I will take more time for it. And doing it more structured.

I: and with the PI?

P3: I guess maybe when you need a counter discussion. Maybe you fill in while you are doing it and you think it is clear for you but for them maybe it is not clear.

P2: If you have a PI who wants to go through all that with you. Because I mean that it also takes quite some time. Normally what you just do is that you elaborate your point by just talking to your PI. And you just say well, that's my thing and this will be my alternative, and this would be my reasoning, and you would get feedback. I think you do not necessarily need a form for that. I think you rather do the form and then go to the PI. I think as also expected if you go to them you already thought through the stuff you want to discuss with them. And that you don't go in: oh well, I just had an idea and now I want to unfold it in front of you.

P1: I do that.

I: What part of the tool do you consider as useful?

P1: Again the fact that you have to formulate the alternatives, that is useful.

I: Is there something you would change?

P1: Yeah, again, maybe on the first part how to phrase the opportunity. Maybe more as a concrete problem you are trying to solve. I don't exactly know how, but I found it hard to narrow it down to like a certain point.

P3: I also don't know how you would do it, but maybe to force you to separate these two things. I don't know if that is possible.

I: So more a problem description.

P1: Yes, I guess it just works better. Like in the example there you really have a problem and then it completely makes sense, the whole thing. Whereas I have stuff that doesn't really makes sense as there wasn't really a problem.

I: What do you think about the last step?

P2: I think it makes sense to put it in. Because then you also have to take the step and decide for what you go.

P1: That is end what you are doing it for. Not only to reflect but also take a decision. But for me it was like, well I just keep on doing what I am doing.

I: So you only need it when there is a problem and you want to decide to do something?

P3: Yes, I guess you sort of integrate all the previous questions you answered and then you sort of use that to answer the last question. So then it does make sense.

I: What do you think about the manual? Is it clear? And did you get enough information?

P1: Yeah it is clear, not too long. That is great.

P4: Yes indeed.

I: How often would you like to use the tool? And how long?

P4: It depends how often. Because since a project can change within a week many times, I don't expect to fill it in every day. But then the last question about action, today I decide to do it one way, this experiment failed and I need to do another action, as to reshape again the project. I think it more helps for bigger pictures than for smaller steps, I think like once a year.

P2: Yeah but I mean you only decide about big things about once a year.

P3: I think you make like this more often. But I think like physically filling in this form, this is something you probably won't do every time.

P1: It could be like when you are really stuck and if you are unlucky this happens every month and if you are lucky that happens twice during your PhD.

P2: It depends on how much it benefits you to really have it on paper. Because anyway you always do that in your mind in some way or another. If you can do it perfectly in your mind, you don't need the paper thing. Just sometime that it helps you. So anyway I would not put it like I have to do this once a year, you just do it as often as you need it.

I: Is it also when useful when you wrote it down, you put it back into the folder and you can look back at it later on. Or you don't think so?

P1: I guess it is so specific for when you are filling it in. So I guess as soon as you wrote like a list of actions at the back, you start doing that. Even if you do it again a week later, it has changed at least a bit. So then you would have to do it again instead of looking at the form.

P2: I think the only reason is to put it out later, is to see what silly thoughts you had. Haha.

I: With who would you like to use the tool? Can you also imagine to do it with a few other people when you work in a group project?

P1: I think maybe then it is even more useful. Because what P2 said, you are doing this in your head all the time. But maybe when you are working in a group, then to explicitly state all these kinds of things might be useful.

P3: You verbalize your thoughts basically.

I: What do you think about the design?

P1: It is nice.

P3: Yeah, with the pictures.

I: I saw you did not see the back in the first place.

P4: Yes

I: So probably we could add something in the design.

P2: A curved arrow or something, that indicates that there is more on the back.

I: Can you think of any add on or something like that? Did you miss something?

P2: You mean like an additions to what is already there? I know what some people do, what I never do, but after taking an action you have another one that you fill in later and basically analyze, ok have I really done what I planned to do and has it worked out. And if not, why not? So they have a later analysis. So you could add that, however personally, I would never to that. It would be just too much effort to just go through my stuff.

P4: I think in paper it is not that helpful that you really have this small space. Maybe if you just fill it in the computer then it is maybe extended.

I: That is a limit of me, as I can't do that.

P1: I think what might actually be nice is with these alternatives if there is some way to really evaluate them next to each other. Cause now the step from how else would you do it to what will this lead to. Somewhere in between there is this that you evaluate them compared to each other and make a decision. And that is maybe, put that more explicitly. So that this alternatives will have this drawback, this alternative has this drawback, this won't have any drawbacks so this might be the best idea.

P2: But that is basically what you have with the outcomes. I would say outcomes it means for different alternatives. So don't just necessarily outcomes. So than you have the consequence of each alternative. And regarding on the consequence you compare them.

P3: Maybe put the alternatives under bullet points or something. And if you like program it, you make it, and you can really see how many alternatives you have.

P1: That you per alternative can give an outcome. Now I just wrote as an outcome usually, like how you did it with the Gibson assembly, like one is the best one. But why is that one the best one, that is actually the main part of this whole thinking process, so maybe you could fill it in somewhere. Maybe I just didn't understand it right.

P3: For the whole flow, like all the block, for me it made sense. So the order and it seems sort of complete to me.

I: Would you actually use the tool if it is available?

P2: Honestly, probably not.

P1: No, me neither.

P4: If you are stuck somewhere, and you need to refresh, go for vacation, then maybe I will also take this one. Maybe on daily basis no, but if something that I need to reshape the whole project for the beginning. Somewhere from the last year, yes.

P3: I agree. I think it really depends on the situation you are in. In some situations you might go back to it, and in other situations you might not really need it.

I: And why won't you use it?

P2: Well, I would say, that you can internalize it. So then at some point when you have a problem, and you feel like it is hard for me to just figure it out in my mind, you just sit down and you start writing the things down that you would write in here. But you don't need a form. I mean you just need an empty sheet and just write it there: this is my problem, this are my considerations and these are the things I could do. And you can do that for yourself, you don't need a form for that actually.

I: This is more like, the guidance, but you don't need the guidance?

P2: Well, if you have internalized it, than I would say no. That is why I guess, in general, it is more nicer for younger people and people starting their PhDs, because they are more likely not having internalized that.

P1: I think it would be more useful to learn how to do reflexivity. Then to actually have a form for that. In the end, this is a sheet with some really obvious words on it. And it is nice to guide, but basically, with only this I could also do the same.

P2: I think it helps you, if you never done it in this way, it helps you to guide you through. Next time you just do the same thing, but then on an empty sheet.

I: Are there any further suggestions?

P2: One thing, couldn't it maybe be more understandable if you would say self-reflection instead of reflexivity. Because kind of everybody knows what self-reflection is. So it might be easier. Otherwise people might think, what?!

I: Or probably just reflection instead of self-reflection, cause it is more like reflection. And what did you think about the name of the method, the mirror tool. Do you think that is clear?

P4: Yes, it is better than reflexivity.

I: I first called it overview form, but that it too generally maybe.

All: haha

P2: That sounds as exotic as Dutch bread.

I: That's actually it. Thank you for the interview and thank you for helping me.

APPENDIX 15. INTERVIEW PROTOCOL PI

Introduction

Now, I would like to interview you on the tool. I would like to record the interview if that is okay by you. This recording will only be used for educational reasons, and the recording nor the information you give to me will be spread. First I will ask you all to give your global impression of the tool.

Global impression

First of all, what did you think of the tool?
What did you like about the tool? What not?
In what way could this tool help PhD students?
In what way could this tool help you?

Implementation at BN
I would like to introduce the tool to first year's PhD students, in what ways is that possible at BN?
How can the tool be implemented at BN/TU Delft?

Future use
How do you envision the future of this tool?
Would you/your PhD students use the tool if it is available?
Do you think your colleagues will use it for their PhD students?

APPENDIX 16. TRANSCRIPT INTERVIEW PI

Global impression

I: First of all, what did you think of the tool?
"Well, I think that anything that is designed to improve the self-reflection and to structure it, is useful. And there are different ways to do it, and we have talked about the milestone structure, that is one. But people might be sensitive to different types of tools. So maybe the milestone structure will work fine for some students or post docs, whereas yours, because it has a different format, people may like it better. So it has some value in the sense that it mend to have a deeper self-reflection, to structure it and to try to extract information from it. So it has some value. Then it is true that some people may do that naturally. But they might not be the best target then. You can always find some master students, if not first year's PhD."

I: What did you like about the tool? What not?
"It is about the level of details. It is difficult to find the right tradeoff. You want something that is broad enough to leave some space to write, to elaborate. But you want some boundaries to have the clear structure for the reflection."

I: This is something quite generic.
"Maybe I could envisage subheadings within alternatives. I would try maybe have two boxes."

I: Or considerations. I now saw at the test that people are using scientific considerations and not ethical.
"That would help maybe to narrow down the scope of some questions, to make them more specific.
Second, I had the feeling that it was naturally converging towards an end product. Even if this is not intended because the target is fundamental research. It stirred towards the benefit is the end product. Even if it is in the long term. It is the gain of knowledge and I consider this gain of knowledge as the final product. It doesn't have to serve any other thing after that."

I: We discussed in the test they only wrote down scientific considerations, they said it is fundamental research so we are not thinking about the end goal and the end goal can change every day or every month. So probably another part of considerations is probably not necessary.

"It doesn't hurt, it is also nice to think beyond your direct research topics. Because when you talk to people outside the research, they have these questions. One approach could be, I don't care so much, I just care about my research. Or you know that you will be exposed to such questions. And you try by having a good self-reflecting beforehand, then you have to tools to address questions from the large public. But I would make it more explicit here. I would make it less vague and provide more criteria/component to let them think in this direction. I think you should guide the self-reflection a bit better. For some people they would do that naturally, for some they would feel a bit lost."

I: In what way could this tool help PhD students?
"Having this self-reflection will help because when they start in the lab, I would not say that all the time it is top-down like I give the project and they work on the project for four year, they could shape the project in many different manners. And they are really actors on that. They are key player. But I think it is good."

I: They will probably take more responsibilities.
"Maybe, that will strengthen for sure. That will strengthen the choice of working on that project. It is not like, oh well, they are nice people, topics looks nice. Let's do a PhD on that. So you have this self-reflection, you try to probe the opportunities, boundaries of the project. Maybe it makes you feel more responsible in the end."

I: In what way could this tool help you?
"Well, anything that helps my group member, indirectly helps me. So it doesn't have to help me directly. Though I believe that it is a very good exercise for me to do that self-reflection on the different project. So then I would not necessarily do that on the minimal cell project as well. But I would rather break it up in the different subprojects that we have. When I gave the milestone structure, I tried to fill in the form myself too and then we confront with the student ideas with that. So I think it is also for me. I will need to have a more finer structure of that to guide my self-reflection to structure it better. It is also a way to commit myself in the project and also to

be an active player in shaping the project. That is also important when communicating about your project. During presentations or in writing a manuscripts you need the structure. You cannot come up with a completely new exotic structure, but most of the time there is a clear chain of ideas that you should have for your project."

I: Actually for the introduction of your paper.
"Yes"

I: Filling it in with PI: first fill in the form and then go to your PI and then discuss.
"I think also this way. And the PI should also fill in the form and then you confront the two. If you do that together with the PI, you might. I would not say that the PI will give some boundaries that will.. No, you want to have free mind to think about that on your own. And it is more constructive if then you confront the student and the PIs ideas."

Implementation at BN
I: If the tool would be introduced to first year's PhD students, in what ways is that possible at BN?
"I think that will be hard to make it a tool that will systematically be applied throughout the department of the faculty. However, if you go to the graduate school. They have some courses/training for first year's PhD students or throughout the duration of the PhD. And within this course you may convince the teachers to talk about the tool. They may talk about different things, to make the life of a PhD student easier and make the project more successful. You have a kick-off training, but you have some other courses and there they can talk about that. And then the student can discuss that with the PI. This is how it went with the milestone structure. One of my PhD students had followed the course of the graduate school. And we talked together about the milestone structure, which was an assignment. And then I decided, oh that's nice, let's try to implement it in the lab. So that's one possibility. So it is a bit indirect, it is through the graduate school. The PhD student taking that course will try to import this tool within the lab. The other approach is yes, go to the PIs, and talk about the tool. And what I could do is, I could certainly give it to my first year PhD student, I have a kickoff discussion, extensive discussion about many different things. And I could just give that to them. In the coming half a year try to fill in the boxes and have a self-reflection on your project. It is not a one-time opportunity that you have, I encourage you to do that in the course of the PhD. But to have something really top-down, like you sign up at BN and you are given that form and you have to fil it in and discuss it with the PIs, that will not work out. Cause the PI will just say no, why do you impose me anything? I am happy to consider it, but then it is up to me to decide whether I give it or not.
To be concrete, I am happy to give it a try in the lab. I guess you have interviewed Jonas. I can maybe shortly talk to him but I can say ok, let's try it. I give that to all master and PhD students and I also give the milestone structure and they make a mix of the two or they do one in place of the other."

Future use
I: Do you think your colleagues will use it for their PhD students?
"I don't know if they have something like that already implemented in the lab. But I think reasonable PIs will consider it. And then they may say no, but I do that in a different matter. But I think everyone would be interested in listening to your story and to try to be convinced. I believe that you will have to be more structured and more finer than this."

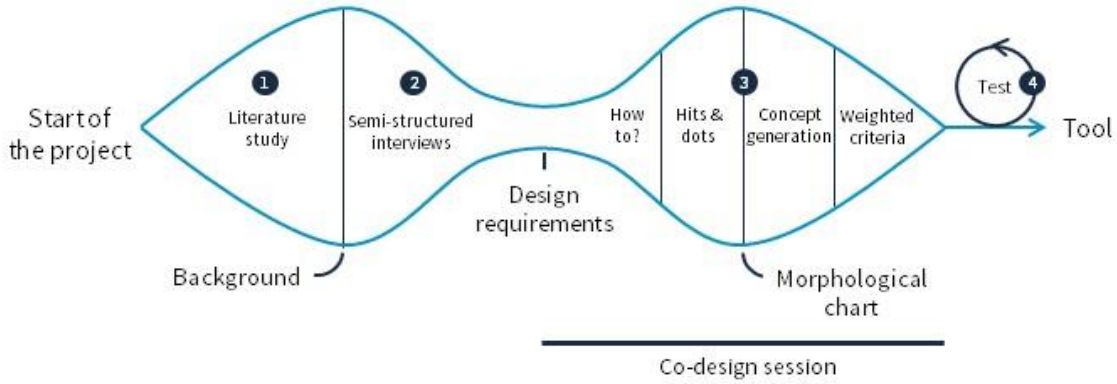
I: I still have to consider if I want to change it now.
"No, I don't know. Because you have based your interviews on that one. But you may want in the appendix to have a second version (2.0) of that, based on the comments that you have received, that you upgrade to a new version. For me that will to be more structured and specific, but maybe others have some other suggestions and you try to compile that."

I: I already changed the manual with the suggestions the PhD students gave me during the test. Because not all of them saw the back and I changed some things in the manual. Like when starting a project and stuck.
"Yeah, I can imagine that there are specific moments that filling in the form is nice. Surely, when you write a paper, as you said for the introduction, that is nice."

APPENDIX 17. ONE PAGE METHODOLOGY

CO-DESIGN APPROACH

This co-design approach can be used to create a tool or method for Responsible Research and Innovation for and with scientists.



Step 1. Literature study

To provide background on your topic & to define design criteria on your topic, do a broad research.

Step 2. Interviews

To provide background on your topic & to define design criteria for your tool, conduct semi-structured interviews with scientists.

Step 3. Co-design session

Organize a co-design session together with a designer and one or more scientists to generate a tool or method.

Step 3a. How to?
Rewrite the design criteria to "How to?"-questions. Let all participants answer the questions on sticky notes individually.

Step 3b. Hits & Dots
Select the favourite, most innovative and most feasible solutions and stick them on a morphological chart.

Step 3c. Concept generation
Generate concepts together or individually using the solutions on the morphological chart.

Step 3d. Weighted criteria
Score all concepts on your five main criteria (1-5). Each criteria can be given a weight according to the importance of each criterium. Discuss the best three concepts with a social scientist and pick the best one.

Step 3e. Final concept
Work out the best concept together with a designer to review several design options.

Step 4. Test with scientists

To review the tool, organize a try-out and a group interview with the target group.

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FIGURE 32: ONE PAGE METHODOLOGY OF THE SELF-DEVELOPED CO-DESIGN METHOD.