CHAPTER TEN
Conclusions and reflections
10 CONCLUSIONS AND REFLECTIONS

In the previous chapters, the sequential steps of a frame reflective Interactive Learning and Action approach to responsible research and innovation in neuroeducation have been described. This process aimed to contribute to the socially robust application of neuroimaging and neurogenomics in the field of education, but also to the further development of a conceptual and methodological framework conducive to responsible research and innovation. The main research question addressed in this thesis is:

*How can we contribute to a responsible research and innovation process of neuroimaging and neurogenomics innovations for the domain of education?*

In order to provide this answer, the four sub-questions will be addressed, of which the first three relate to the neuroeducation domain-specific opportunities and concerns, and the last the RRI process. After this, the limitations faced in conducting this study are discussed. Finally, some ideas on ways to proceed with regard to both RRI theory and methods, and to the neuroeducation domain will be presented.

## 10.1 Conclusions

### 10.1.1 Guiding visions in the field of neuroeducation

The two technologies for which guiding visions were identified and developed will be discussed separately below, as the research into guiding visions demonstrated that the two fields are in different innovation development stages.
Neurogenomics

The exploratory study to identify guiding visions of neurogenomics in the context of learning and education showed that in the literature, future visions concerning the implications of neurogenomics for the practice of education are generally absent (see chapter 5). Although the field of neurogenomics is developing rapidly, articles are predominantly oriented towards medical practice, focusing on the diagnosis, prevention, treatment and prognosis of learning disorders. Genomics research into more general phenomena such as intelligence is performed, but future visions expressed in articles reporting this research typically involve the understanding of the general biological determinants of these phenomena, without mentioning the translation of this information into applications in education.

Subsequently, interviews and a focus group were conducted with experts in the field of neurogenomics and neurogenetics research with potential relevance to the domain of education. As no researchers identify themselves as such, it was difficult to pinpoint who exactly comprise the field of neurogenomics for education in the Netherlands. The scientists that were involved in our study came from different disciplinary backgrounds and had different empirical practices. They did not share guiding visions for the domain of education; different second order notions influenced their idea of the future. In particular, perspectives of genomics researchers seem to be far from researchers from the field of education involved in genetic research. In some cases, a different understanding of key concepts even created a tension between guiding visions. For example, this was the case with regard to the idea of tailor-made educational strategies of more high-throughput genomics researchers, which was not supported by researchers involved in hypothesis-driven research into the genetics of early childhood behaviour. An absence of visions for education in literature and a lack of shared visions in the interviews and focus groups are indicators that the field of educational neurogenomics hardly exists yet, at least not in The Netherlands.

Neuroimaging

A different picture was seen with regard to applications of neuroimaging for education. In order to identify future visions of neuroimaging for the domain of learning and education, a literature study was conducted, followed by exploratory
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interviews and two focus groups with neuroimaging experts involved in education research from various Dutch universities. Two main trends within the guiding visions were identified, which served as point of departure for the subsequent research steps: visions related to the use of neuroimaging on (1) an individual level, to gain more insight into individual brain specificities, thereby contributing to personalized learning (see chapter 7), and (2) a population level, as a tool for gaining more general insight into how the brain works thus contributing to evidence-based learning (see chapter 8).

With the establishment of the HCMI\(^{21}\) program, evidence-based learning has been a clear point on the neuroscience agenda, and this was reflected by the interviews and focus groups with neuroimaging experts. However, the way in which this information could contribute to a more evidence-based education practice was clearly not straightforward for scientists. Some scientists were critical towards the idea that neuroimaging could give insight into how the education practice should be shaped, arguing that neuroimaging research is a hypothesis-generating approach necessitating follow-up education research before implementation is possible. In contrast, others were frustrated by the fact that educators were not yet implementing their research results. These opposing views seem related to the distance of the researcher to educational practice: the further away from the classroom their research takes place, the more they see opportunities for implementation of neuroeducation research to that practice.

The second vision concerns a very different use of the technology, involving a transition of neuroimaging from a population level to the level of individual testing. This vision is also described in the book Brain Visions (Van Keulen, 2008) published by the The Netherlands Study Centre for Technology Trends (STT), and the Dana foundation’s Cerebrum (2010). During the interviews and focus groups, participants discussed how individual scanning could offer possibilities for the development of personalized learning plans, based on the early diagnosis of learning disorders, the adaptation of teaching to sensitive periods within brain development, the assessment and monitoring of individual capabilities, and the development of adaptive learning systems. However, not all experts agreed this was a good idea for the future,

\(^{21}\) HCMI is the Brain, Cognition and Societal Innovation program of NWO
participants mostly referring to technological limitations and arguing that it would not be possible to make valid individual statements using fMRI.

As shown here, the two neurotechnologies central to this thesis are in different technology development phases. With regard to genomics, the different viewpoints could be mutually enriching but interactions between disciplines do not yet frequently occur. It was decided to focus transdisciplinary efforts in subsequent phases on neuroimaging and take evidence-based learning and personalized learning as a starting point for the discussion with societal stakeholders, as will be discussed in 10.1.3.

10.1.2 Boundary issues

The oft-discussed gap between neuroscience research and educational practice has been examined by interviewing people at the boundary: neuroeducation researchers and education professionals already playing an intermediary role between these two fields. The analysis of boundary people, boundary objects, and boundary work is described in chapter six. Many small initiatives were encountered that aim to bridge the gap and to integrate neuroscience more in educational practice. The main barriers identified relate to what bridging the boundary actually means: how research should be communicated and disseminated, who has responsibility for what, at which stage research is applicable to practice, and how these results should be translated. The way that researchers and educational professionals demarcate research from practice is evidence that they are performing boundary work. Boundary work starts with the use of the word “gap”. Most scientists involved in neuroeducation research described the gap as a space that exists between research and education practice as their contexts are distinctly dissimilar.

An important barrier mentioned is the existence of neuromyths, the misunderstanding of research results in practice, and the educational practice running away with scientifically weak findings in the name of brain based learning. In other words, they were afraid that education practice would succumb to the hype. This makes researchers extra careful in the way they communicate and interact with practice. On the other hand, the education professionals were frustrated by the ad-hoc quality of their interaction with neuroscientists, and have embarked on doing bridging work
themselves by selecting relevant research and translating this to their own practice. It can be argued that in this way a loop is created, as this process contributes to the image of brain-based learning described above, which then only reinforces the gap.

Stakeholders themselves contribute to the boundary between the two fields when they describe neuroeducation as the translation of neuroscience to education, as this reifies the image of two separate islands. The same holds true with regard to the problems scientific stakeholders describe with achieving a balance between, on the one hand creating enthusiasm for research in an early phase, but on the other hand, not giving into the hype. By arguing that it is necessary to find the “right” moment for translation, translation is described as a one-way process, coming from a top-down perspective on knowledge dissemination. Similarly, when the question is raised who is responsible for neuroeducation, this reinforces the idea that science and practice should be thought of as separate entities, besides it being very impractical to place responsibility on one of the two sides. Bridging the boundary should therefore be a joint effort, not only in the sense that both research and practice should take their responsibilities, but that both sides should work at neuroeducation together.

Many of the boundary practices encountered are ad hoc initiatives, with researchers defining the agenda, consisting of mostly data collection or information dissemination. In order to go beyond the conception of bridging the gap as moving packages of knowledge back and forth, it is necessary to think about new ways of integrating knowledge by restructuring knowledge systems. If neuroeducation is conceptualized as a knowledge community, with all stakeholders working together from the beginning in formulating what the common good is and what desirable applications are, research questions can be developed that are the responsibility of all parties. An important starting point for such a community would be recognition that both sides of the boundary have their own expertise to bring to the table. This would mean that the perspective of education professionals has to be taken more seriously in defining how neuroscience can help them in their understanding of teaching and learning and to enable them to make the most of neuroscience in their own local practice.
10.1.3 Frame complexities underlying scientific future visions

Chapters seven and eight describe the results of focus groups with teachers, secondary school children and the parents of secondary school children in which they reflected on the application of neuroimaging (1) as an evidence base within the context of education and (2) as a tool for personalized learning. Although these discussions were very different, it was possible to distinguish four main frame elements that were central to both topics: the learning child, education, the brain and neuroimaging. Answering the question “how do you evaluate the application of neuroimaging in the classroom?” can therefore be visualized as a series of four steps, as seen in figure 10.1.

The visualization presented here illustrates the different ways in which participants can approach the four frame elements during their construction of an argument. The values and worldviews that can lead to a different conceptualization of these elements are shown on the right side of the figure. The elements cannot be viewed separately, but also take on meaning in relation to each other. For example, if a parent argues that individual neuroimaging could contribute to better education because every child is unique, they focus on the element of the child, but in doing so they also shed insight into how they interpret education, the brain and neuroimaging. By examining these elements together, it is possible to reconstruct their frame of meaning.

This figure gives an overview of many different frame complexities, both within elements (is a brain scan only a snapshot or can it give insight into patterns?) and between elements (does a brain scan reduce a child to their brain function?). These complexities have been described in detail in chapter seven, eight and nine. Here, we give insight into the most dominant frame conflicts encountered with regard to personalized learning and evidence-based education.
The first important frame conflict emerges in relation to the means and ends of education, which our results show are not perceived as a given by societal stakeholders. Samuels (2009 p. 48) elegantly states:

How do you evaluate the application of neuroimaging in the classroom?

Figure 10.1: Overview of frame complexities
“The question, “What does it mean to be educated?” is a difficult, value-laden concern that educators must grapple with not only in armchair theorizing but also to inform their approach to pedagogy, which can never be ideologically neutral or objective.”

This also holds true for applications of neuroimaging. During the focus groups, participants expressed very different ideas about what children should acquire from their education. This is associated with both value and world-view conflicts: for example, should all children be treated equally or according to their needs and should education focus on optimal achievement or should children given freedom? It can be argued that the introduction of hypothetical applications with the potential to change day-to-day education practice brings new focus and urgency to the discussion about the aims and ends of education. In order to contribute to socially responsible innovation, it is necessary to redefine the purpose of education. It is highly likely that we will not reach a consensus about this challenging topic. However, this should be the first question asked in order to assess how neuroimaging could contribute in a desirable way to practice. The way in which stakeholders frame “good education” determines how they define problems and their corresponding solutions with respect to the application of neuroimaging in education.

Second, with regard to the value of neuroimaging as an evidence base, conflict arises within the framing of the element of education: whether the classroom is seen as complex or as controllable, and also in the way the value of teacher’s experiential knowledge is assessed. An argument frequently made during the focus groups and the interviews with intermediary parties is that, even if neuroimaging were a technology with very objective results, teachers using this evidence have to apply it within the specific complex reality of their classroom. This contrasts with the framing of most of the neuroscientists involved in this study, who argued that teaching methods developed on the basis of neuroimaging results first have to be thoroughly tested in practice, because otherwise they might for instance give rise to neuromyths. However, in the perspective of many societal stakeholders, and as also argued by Morrison (2001), controlled trials in education might not be feasible. This brings into question when knowledge about the brain is suitable for application within practice, and whether the same rigorous standards in health care are applicable for education. Educators are enthusiastic about brain and learning, because this can serve as an
inspiration for their day-to-day work, and can make them more critical to their own teaching approaches. This is in line with Pickering’s findings (2007), namely that teachers do not simply want to be told “what works”, as has been argued by Goswami (2006), but that they want to be given the tools to make decisions that work for them, in the context of their own practice. These choices are then perhaps not evidence-based but evidence-informed. Hardiman et al. (2011) argue that in this sense, neuroeducation is not different from other neuro-disciplines, with practitioners on the ground taking new research and adapting it for their own purposes, establishing their own standards for pragmatic utility.

In his article on the democratic deficit in educational research, Biesta (2007) describes two roles of research in informing educational practice, based on de Vries (1995): the technical role, which is about the application of strategies for predetermined ends, and the cultural role, which is about helping educational practitioners to acquire a different understanding of their practice. De Vries (1995) argues that a democratic society, in which ends are not a given, is characterized by this cultural role of research, with research providing another perspective to an open discussion about the aims and ends of our educational endeavours. The results show that neuroeducation researchers mainly see the technical role of research, but that educators are more interested in the cultural role.

Third, we see frame conflicts relating to neuroimaging. We have seen that some stakeholders frame neuroimaging as an objective way of doing research, while others argue that neuroimaging is reductionist, not only reducing a child to his/her brain, but also narrowly defining performance/learning, disregarding for example creativity, curiosity, or social interaction. We have seen that neuroscientists were quite aware of this reductionist argument and provided solutions for this issue. For example, neuroimaging research always needs to be embedded in a broader context of education research, and neuroimaging research should be concerned with learning in a broad sense. However, these ideas are not often put into practice.

The results show that frame conflicts do not necessarily take place between different stakeholder groups, but also within these groups, as also seen by Kupper and de Cock Buning (2010) and Arentshorst (2014). In The Reflective Practitioner, Schön (1995) describes the emergence of professional pluralism. Professionals hold competing and
shifting images of their own role as they respond to “uncertainty, complexity, instability, uniqueness, and value conflict” within their practice (Schön 1995, p. 17). Schön calls this the “artfulness” within professional practice. With regard to both individualized neuroimaging and neuroevidence-based education, there is no easy way to consider all the different aspects that are relevant to this discussion, because the devil is in the details: we do not know what these applications will mean for the individual child, in the context of a specific classroom. Just as educational professionals negotiate their perspective within different situations, the different possibilities neuroimaging can provide for education need to be renegotiated with relevant stakeholders as they come into focus more clearly.

10.1.4 The facilitation and design of a science-society dialogue

In chapter three, three main issues encountered in designing and implementing an RRI process are reflected on: the problem that the technologies are still in an early phase, the wide variety of values and expertise amongst stakeholders, and the constraints emerging from the institutional structures in which research and development take place. In this section insight is given into the benefits and limitations of a frame reflective Interactive Learning and Action approach with regard to these issues.

Technology in an early phase

In order to anticipate on possible futures of a technology while concrete applications are still absent, this study started with the guiding visions of scientists doing research with potential relevance to education using neuroimaging or neurogenomics technologies. Rather than technology, this research focused on innovation, or the application of technology within a specific domain. This has proven to complicate the RRI process to some extent. First of all, the application within education has influenced our choices of who to include in this process. As innovations are complex, many actors are involved in their development, and knowledge about the technology is fragmented, with less actors having an overview of where the development of a technology is heading, especially outside of its original domain of health care. It can be argued that this issue can partly be resolved by the selection of participants and partly by the process of constructing guiding visions, e.g. it is better to involve more
senior researchers, as they have an optimal overview of what is happening within the field and direct connection to technology development.

With regard to the process of constructing guiding visions, focus groups were considered very important. During the interviews, researchers had difficulties thinking outside the box of what is feasible with the technology in the present. During the focus groups however, the participants were able to construct guiding visions that were less subject to current technological limitations. It is likely that this setting is more conducive to the formulation of guiding visions because the atmosphere during a focus group is generally less formal, participants are able to learn from each other, inspire each other, and because they share responsibility for the visions constructed.

The second issue encountered in this RRI process, is specific to the field of neurogenomics, for which future visions mainly outside the domain of health care were constructed. The question is whether neuroimaging is simply in a later development phase or if it has more relevance to education. Arguments can be given for both explanations. Neuroimaging is already informing our understanding of learning, which makes the link to individualized imaging in the context of education perhaps easier to imagine. Applications of genetics and genomics are becoming increasingly important within health care. It is possible that this embedding in health care makes it more difficult to deliberate with scientists on futures within education. Therefore, when a technology is just emerging, it may be better not to limit deliberations about the application of a technology to a specific domain in the first place. RRI can start from guiding visions, but then the researchers themselves need to identify for which domains their research has relevance. The benefits of this approach are that the researchers themselves have more ownership and commitment towards the visions they have formulated and that the RRI practitioner assumes a neutral position. A drawback of this approach is that applications outside of the domain in which a technology is currently developed may not be anticipated on.

This raises questions about how to deal with ‘function creep’, a term often used in discussions about privacy (Berghuis & Scheepmaker, 2011). Function creep refers to changes in, and especially additions to, the use of a technology, for example when technology applied within one domain slowly finds its way into other domains (Dahl & Saeligtnan, 2009). Both neurogenomics and neuroimaging provide insight into
biological pathways of the brain, thereby shifting the boundaries between health and disease, normal and abnormal. Not only can applications of these technologies ‘creep’ into other domains, technology also contributes to blurring the distinction between the domains. One suggestion for dealing with this issue is that if there are indications that a technology has relevance for a new domain, guiding visions could be constructed with the front-runners within this field. However, since it might be difficult for a scientist to imagine desirable futures outside the scope of a his/her domain, it might be useful to partially let go of this notion of expectations, and to also discuss with scientists “what-if’s” and “what else might it do?” questions (Owen et al., 2013) in other domains, to stimulate ‘thinking out of the box’ even more. This can also be argued to contribute to the reflexivity of scientists, who are forced to think about potential future impacts of their research on domains other than their own.

Value Pluralism

The second issue central to the design of this research project is the existence of value pluralism amongst scientific and societal stakeholders. In figure 10.1 on page 177 a graphic depiction is given of the many different perspectives existing amongst stakeholders. Stakeholders have been recognized as holding competing and fluid images of their own role as they respond to shifting demands within their practice. Therefore, responsible research and innovation requires a pragmatic approach that facilitates a process in which specific applications can be renegotiated with relevant stakeholders at the moment they emerge.

This thesis describes the first steps within such a process. In order to get to the root of (dis)agreement between stakeholders from multiple backgrounds, the RRI practitioner needs to develop an understanding of the elements that make up the arguments given, and determine the exact element of conflict. Take for example the way that stakeholders frame “education”. One perspective can be that neuroimaging puts too much emphasis on the optimization of children’s development, thereby reducing a child to a “learning machine”, which could conflict with the view that children need to be able to develop to their full potential. These conflicting arguments are based on different values and this needs to be made explicit during the process. Only then stakeholders can discuss whether innovation can be shaped in such a way that both values are taken into account. A different argument could be that one of the important
goals of schools is to provide a safe and social environment for children. This argument may be less value-based and rooted in a different understanding of the application neuroimaging would look like, and therefore offers more room for negotiation. These are but some of many framing varieties, and this research has tried to untangle and categorize them. This provided insight into which conflicting views are grounded in conflicting values, and which are grounded in conflicting understandings or even misunderstandings. It is important to define which is which in these kinds of conflicts as it is difficult to come to a consensus about values, which are part of people’s identity (Bohman, 1996), while conflicting understandings or misunderstandings are easier to negotiate. For example, with regard to personalized learning, stakeholders frequently had different understandings of what “personalized” or “individualized” would mean for practice. Many stakeholders were afraid that personalized learning would be at the expense of social learning, because individual neuroimaging focuses on the individual brain. However, this does not necessarily have to be the case, as personalized can also be interpreted as “adapted to personal needs”, which can include social needs. Although part of the frame conflict here can be attributed to misunderstanding, this situation does show the importance of also doing neuroimaging research into social learning.

A learning point during this process has been that it is important to pay equal attention to the different frame elements. The different stakeholder groups tended to focus on different elements within their framing. For example, although teachers may hold different perspectives with regard to the balance between individual learning achievement and the social component of schools, they are inclined to focus on the child and the means and ends of education in their discourse. Parents’ expertise lies with the child so this tends to be the element that they bring to the forefront. Neuroimaging experts know most about the scan so this is the element they often structure their argument around. However, this realization is as common-sensical as it is important, as this difference in issue framing can explain why it is difficult to find common ground in discussions between different stakeholder groups. For example, many parents were afraid that individual neuroimaging would lead to labelling and stigmatization. Neuroscientists often argued that this is an invalid argument because the brain is more plastic than previously thought, in addition to it being impossible to predict future capacities of the child in light of technical limitations and the influence of environmental factors. However, this does not resonate with the frame element that
parents find important, the child. During the dialogue session it was observed that scientific arguments often trump experiential ones, perhaps because scientific expertise was limited to scientific stakeholders, while all participants are stakeholders in education. This phenomenon was also recognized by Mogendorff (2014) in her discursive analysis of multi-stakeholder dialogue settings. This is problematic if it causes scientists not to take opinions different from their own seriously because they forget that society is not homogenous. In order to do more justice to societal stakeholders their way of framing neuroimaging has been taken as a starting point within the dialogue session. This approach showed that the frame elements considered important by societal stakeholders can also be used as a source of inspiration for developing new research questions, relating to creativity, motivation, curiosity and social learning.

One final note I want to make here is that the facilitation of a process focusing on values can obscure the use of strategic arguments. In our theoretical framework, it was argued that problems and solutions stakeholders formulate are based on their second order notions: their values, beliefs and worldviews. However, different stakeholders also all have their own interests in the development of neuroimaging for education that could influence the values and worldviews they express. Teachers do not want to lose their job and possibly some changes in their day-to-day practice could be unwanted. Similarly, imaging researchers have the funding of their research to consider. These are of course valid arguments but it is important to design the process in such a way that it is not overtaken by power dynamics. It can be argued that deliberations in which conflicting interests play a role can benefit from a frame reflective approach. This process creates room for different stakeholders to make their interests explicit, describe why they think these interests are threatened, and specify which elements of the application are perceived to affect whom and in which way. This is again all related to their framing of the issue. In this sense, socially responsible research and innovation can be regarded as research that is desirable from all perspectives but also contributes to mutual gain.

The situation gets more complicated when arguments are given (intentionally or unintentionally) to steer the discussion away from morally problematic situations, as described by Dewulf and Bouwen (2012) and as shown in chapter nine. The notion that the brain is plastic could for example be argued to have strategic value, inhibiting
further discussions about using neuroimaging to gain insight into individual capacities. Nevertheless, issues of privacy, stigma and discrimination still need to be discussed. It is important that facilitators of a RRI process are aware of these interests and that they provide all stakeholders with the space necessary to interact with the different aspects of an issue, even though others may “disconnect” or “polarize” (Dewulf & Bouwen, 2012) certain frame elements. If facilitators are capable of recognizing the different interaction strategies at play during dialogue (as described in chapter nine), they can intervene when participants do not want to connect to other stakeholders’ ways of framing by making this disconnect explicit.

A research structure conducive to returning to “business as usual”

Various scholars have raised concerns about what happens after deliberation processes and caution us to guard against scientists once again dominating decision-making processes on research, and societal stakeholders moving to the back seat (Hagendijk & Irwin, 2006). Deliberative democratic theorists are sometimes criticized for being naïve, there being many external factors that play a role in decision-making processes in science and technology (Hagendijk & Irwin, 2006). In accounting for these factors and the barriers to inclusive research and innovation processes, scholars often use a systems perspective (see for example Kloet et al., 2013, Roelofsen et al., 2011, Arentshorst et al., 2014). Major barriers that have been identified in other research, which are also visible in this study, are the monodisciplinary nature of academic disciplines, insufficient interaction with societal stakeholders of academic research and research constraints provided by funding conditions (Kloet et al., 2013). Although a systems perspective is useful for understanding these research dynamics, it is also important to examine spaces within research structures that can contribute to RRI at a local level.

Instead of focusing on external barriers this project aimed at acquiring insight into the extent to which participating stakeholders themselves construct barriers and provide bridging opportunities for responsible research and innovation, by looking at processes occurring at the boundary of neuroscience and education. Such a bottom-up approach offers intervention possibilities for the RRI practitioner. An analysis of successful boundary practices can shed light on what works within local contexts, and why. Key to a process that does not come to a standstill due to systemic constraints is
the commitment of actors to the RRI process. The identification of actors that are committed to bridging this boundary, and understanding the reasons for their commitment, can be a first step in this process. This research shows that some scientific stakeholders find it important that their research can be implemented in practice, but that their perspective on how this implementation should take place is informed by a research framework that actually reinforces boundaries. The facilitation of reflexivity amongst researchers towards this type of discourse and ways of thinking, that actually create boundaries, can be another step in dissolving them. In line with Giddens’ conception of the duality of structure (1984), it can be argued that boundary work on the one hand reinforces systemic barriers, and on the other hand scientific structure gives rise to boundary work. However, it is important that systemic constraints are not used as an excuse for maintaining the status quo with respect to innovation trajectories.

This project was not conducted as part of a research consortium. At the start of this project, this was mainly seen as an important constraint, because it was difficult to find scientific stakeholders willing to engage with societal stakeholders in order to develop broadly shared research questions. In the end however, we have found that this process of identifying actors that are internally motivated to do research relevant and desirable for practice, is actually an important step in this process. If scientific stakeholders are engaged with RRI because this is mandatory within their specific research project, as was the case in the ecogenomics consortium conducted by Roelofsen and Kloet (2012; 2013), it is highly likely that after these formal demands are met, researchers will return to business as usual. However, it is necessary that stakeholders continue their mutual engagement even after the RRI practitioner has taken a step back (ironically this is often due to constraints within the research system!), which can only be achieved if stakeholders are committed to RRI because they consider it to be in their own interest. It can therefore be argued that focusing solely on relieving barriers within the institutional structure of science is not likely to contribute to RRI, especially when researchers are forced to be part of a process they see no benefit in. This point is also made by Elberse (2013) with regard to patient participation in research, distinguishing between structural and sustained participation, the former allowing patients a seat at the table but without guaranteeing their actual influence on decision-making processes, while the latter also impacts research culture, implying a shift in the thinking of researchers.
10.2 Overall conclusions

From this research the following main conclusions can be drawn:

The research described in this thesis contributes to Responsible Research and Innovation with the development and testing of an approach in which interactive learning and action is integrated with frame reflection. This type of reflection on guiding visions has proven to be beneficial in disentangling the complexity of these applications by providing structure to the way in which stakeholders, from science and society, perceive different elements of neuroimaging innovation possibilities.

With regard to the formulation of what constitutes desirable use of neuroimaging (research) for evidence-based learning and personalized learning, the results of this process show frame complexities in various forms. The existence of these frame conflicts demonstrates the importance and relevance of the inclusion of societal stakeholders in research and innovation processes. Education is a field that is value- and context-based, and scientific evidence should not be conceived as a way to "align" different perspectives or as an excuse to skip deliberation about the means and ends of education.

The results of this study also demonstrate the existence of frame complexities relating to the way in which the boundary between research and practice can be conceptualized. This way of looking at research structures offers opportunities for intervention by RRI practitioners and shows that some of the perceived barriers to (responsible) research and innovation can be reframed without necessitating top-down changes to research policy.

Although the impact of this RRI approach on the field of neuroeducation was local and restricted to those involved in this study, the experience has provided further insight into how deliberations between science and practice can be organized in order to contribute to the reflexivity of researchers, such as making the process transparent to create ownership for the outcomes. To some extent the interactions between relevant actors resulted in increased awareness of participating stakeholders of different frames and areas of frame conflict, new ideas for future research and in the formation of new contacts/networks.
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This study should be considered as a first step within an extended RRI process in this field, as results show that on-going deliberations between research and practice are required as the future of neuroimaging comes into focus more clearly and stakeholders make sense of the possibilities this technology can bring to education.

10.3 Internal and external validity

Several strategies have been used to enhance the internal and external validity of the results, as have been described in chapter four. How these strategies have worked in practice will be discussed in this section.

10.3.1 Internal Validity

First of all, the role of the RRI practitioner conducting this research has been central to the way the project has been designed and implemented. The benefit of taking on this central role is that the practitioner has been close to the data and the context in which the different experiments took place. However, as this thesis is about facilitating reflexivity, this also means that the practitioner needs to be reflexive towards her own practice and the design of the separate phases and social experiments. By identifying future visions, representing them to societal stakeholders, and re-representing these views during the dialogue session, it can be argued the RRI practitioner is in fact creating a new kind of boundary object. In the identification of guiding visions, used as a basis for reflection and therefore integral to the construction of desirable futures, a role is taken on that is not completely neutral.

Therefore, in order to enhance the validity of the study, guiding visions have been constructed using a triangulation of research methods: a literature study, interviews, focus groups and a dialogue meeting. In addition, at different times during the study stakeholders of this RRI process were asked to reflect on the research results: during the interviews with scientific experts they have reflected on the literature study, and before the dialogue session the participants were sent an extensive summary of the research findings, which was further reflected on during the dialogue session. Furthermore, the research process has been designed and implemented in consultation with a supervisory committee and a valorisation panel. The supervisory
committee consisted of three senior neuroscientists with an overview of the neuroscience field. At various times during the research process, they provided suggestions on who to include as scientific stakeholders and reflected on the results of the study. In addition, one of the committee members took on a central role in the organization of the dialogue session. The valorisation panel consisted of societal stakeholders and policymakers. They gave feedback on the results of this study and how these could be disseminated.

The decision was taken to focus on two kinds of future applications, and can be argued to be a categorization rather than a selection of applications. This categorization was deemed necessary because these applications are distinct, but even though they have been discussed separately, perspectives about one kind of application (mainly individualized scanning) also featured in the discussion about the other application (evidence-based learning). It can be argued that the RRI practitioners involved in this study have contributed to the hype by engaging stakeholders in a reflection on individualized scanning when this technology does not yet exist and may never be developed. In addition, it is possible that some future visions were left out of this study, although this is not likely because the methodology aimed at achieving data saturation (see section 10.3.3).

Although the focus groups and dialogue session have been designed in a step-by-step manner, in consultation with other researchers at the Athena Institute, the facilitation process relies on the actions of the researcher in the moment. For some parts of the study, it was not possible that the same facilitator facilitated all the different experiments, and sometimes other researchers of the project team were invited as facilitators. This has both benefits and drawbacks: involving other facilitators contributed to the objectivity of the study, but because these facilitators were less involved in the study they could have been less aware of all the different aspects relevant to the study.

10.3.2 Inclusion and representation

It can be argued that creating commitment to responsible research and innovation as an approach can sometimes be at odds with the ability to have an overview of the frame complexities. Commitment means that stakeholders need to be invested in
neuroimaging or neurogenomics and education in some way. However, most societal stakeholders currently have little relation to these technologies, and those that are invested, such as the intermediary parties, often have a positive view of the potential of these technologies. In order to gain insight into the variety of perspectives present within society, an agency was commissioned to recruit a broad range of stakeholders (teachers and parents) for the focus groups. This was more in the interest of the research process and the representation of all the different values, than in the interest of creating a learning community with participants interested in engaging with responsible research and innovation. A different choice was made for the dialogue session, for which we invited previous participants in the process that appeared motivated to be a part of a responsible research and innovation community. This meant that during the dialogue session, even though more teachers were invited than other stakeholders, this group was clearly underrepresented, because they did not prioritize this discussion within their agendas. This made it difficult for the teachers that were present to assert their values and expertise to the other participants, who all had more expertise on the level of neuroimaging and neuroeducation.

Some other minor points with regard to stakeholder representation can be made. In the selection of teachers for the focus groups, more attention could have been paid to the representation of diverse teaching subjects within each group. The research results indicate that their teaching background could be of influence to their perspective. With regard to the participating secondary school children, a pragmatic choice was made to include secondary school children attending one particular subject at one school. This means that many children are not represented in this study, including children of primary education and children attending secondary schools at a different level. The younger the age of children and the lower their level of education, the more difficult it is to discuss with them the consequences of a possible high technological innovation. However, it is possible that their age and school level has consequences for their perspective on neuroimaging as well. Further research into this difference would be advised.

10.3.3 Saturation

In the field of neurogenomics there is only a small group of scientists from which to choose, this resulted in a limited number of interviews with neurogenomics experts.
With respect to neuroimaging, interviews with neuroeducation experts continued until they did not yield any new information. An adequate number of focus groups with societal stakeholders about evidence-based learning (n=10) and personalized learning (n=10) was conducted to achieve saturation. However, only one dialogue session was organized, albeit with multiple parallel stakeholder groups. Additional sessions were not deemed feasible because of the limited number of researchers committed to the RRI process, but would have been desirable as they could have contributed more insight into how to manage frame differences during these sessions, and whether the sessions had different results due to their composition or the topic being discussed.

10.4 External validity

The research described in this thesis is about one specific case study, relating to one specific technology applied to one specific domain. With regard to this domain, the results of this thesis are in line with other qualitative research into the perspectives of educators on neuroeducation (Hardiman et al., 2011; Pickering & Howard Jones, 2007) and scholarly voices that are critical to the ascendancy of the idea of an evidence-based education practice (Biesta, 2007; Pirrie, 2001). In other respects, this has been research pioneering societal views on future applications of neuroimaging, and there is no academic literature with which it can be compared.

Specific to this research is the application of a frame reflective and boundary sensitive interactive learning and action approach to responsible research and innovation. The approach and methodological design used in this study could be relevant for research into RRI in the field of new and emerging science and technology (NEST), but also for other types of multi-stakeholder processes and transdisciplinary research into complex, real-world problems inclusive of environmental issues.

RRI can be considered as an emerging way of doing research, but it has its roots in Technology Assessment, an approach originating already in the 1960s, and more specifically CTA, which was developed over 25 years ago. However, the experimentation with multi-stakeholder approaches in the development of socially responsible research and innovation is only a recent phenomenon, and has mostly taken place within specific domains, such as ecogenomics (Roelofs et al., 2010a), nanotechnology (Van Merkerk, 2007) or synthetic biology (Betten et al., 2013). In this
study, the RRI approach was applied to neuroimaging innovations, and this technology can only be compared to other emerging technologies to a certain extent. Furthermore, this study focused on innovations within education, which is a very specific domain, in the specific context of The Netherlands. For example, Roelofsen’s (2010a) and Kloet’s (2011) research on ecogenomics focused less on the ethical aspects of research, and more on increasing the societal relevance of research, because the applications of ecogenomics were less contested within society. One of the most important points learned, while using methodologies developed for RRI research concerning other technologies, within this study has been that the specifics of the technology and the domain of application make all the difference. Besides technologies and innovation having different societal implications, research and innovation take place within specific structures, involving a specific set of actors in research and practice. Therefore, in order to contribute to a process in which all stakes involved are carefully considered, there can be no one formula for approaching RRI. Instead, research approaches need to be tailored to the context of the research and technology domain. The Neurosciences in Dialogue project itself, focusing on three different domains (education, health care and security and justice), makes clear how important this is. Although all three subprojects focus on the same technology, the innovations within the different domains are in different phases, different actors are involved, and the domains of applications give rise to different opportunities and concerns.

That being said, the emergent design of the interactive learning and action approach provides room to tailor the process to the context encountered. Key to this approach is an iterative process that starts with an exploration of research structures and actors, who themselves play an important role in determining how the rest of the process is designed. In addition, the frame reflective approach that has been described in this thesis can contribute to the quality of stakeholder participation in other research. Frame reflective approaches have been used in the context of deliberations on animal welfare (Kupper & Cock Buning, 2010) in order to widen and deepen the different stakeholder perspectives. Finally, within Science and Technology Studies (STS), the boundary between science and technology has often been reflected upon by other scholars (sources) who have also suggested the need to reconceptualise the issue at hand in such a way that different stakeholders are accorded symmetric treatment in hybrid forums (Callon & Rabeharissoa, 2003; Garud, Gehman, & Karunakaran, 2013).
10.5 The way forward: suggestions for future research and innovation

In this final section we provide some suggestions for further research that would contribute to RRI in general and to the fields of neurogenomics and neuroimaging for the domain of education specifically.

As discussed in the previous section, the results of the research presented in this thesis are expected to be of broader relevance for RRI in other emerging science and technology fields and for other research involving the participation of a broad range of stakeholders. Therefore, the replication within other contexts of the social experiments conducted within this research would be of value for the validation of this study and the further development of this approach. Specifically, the design of the dialogue session, in which participants were facilitated to reframe current concerns into areas of desirable research, could be experimented with further. This part of this research project would benefit from further validation and could also be fine tuned by taking the lessons learnt into account.

This research has contributed to RRI by anticipating on future developments, stimulating reflectivity among scientists and introducing a broad range of stakeholders in deliberations. However, the fourth aspect of Owen et al.’s (2013) description of RRI, responsiveness, could benefit from further investigation. Although attention was paid to what kind of research would contribute to more desirable applications within education during the dialogue sessions, these have not lead to concrete action. A further step that could be taken would be to translate the opportunities and concerns for neuroimaging research in the domain of education into research agenda’s. In addition, further research could be done into how to facilitate a RRI process in such a way that stakeholders from science and society are committed to its outcomes and more responsive to its effects.

With regard to the neurogenomics exploration, it is clear that more research is necessary into ways to deal with an incremental shift of this specific medical technology into education, but also into more general instances of function creep. It would be useful to gain more insight into how we can anticipate such a shift, as these applications are not part of the guiding visions of scientists. One possibility could be to start the discussion about the application of neurogenomics in the domain of education, from the societal side, by gaining insight into potential end users’ guiding
visions for education and investigating in which way neurogenomics could contribute to the realization of these desirable futures.

Within this thesis, much attention has been given to ways in which neuroimaging could contribute to a desirable future for education. If presented with the opportunity to continue working within the field of neuroeducation, the author would want to follow up her research specifically in two areas. The first area relates to individualized neuroimaging for personalized learning, for which deliberations have only just begun. As technology creates possibilities for applications not even imagined before the technology was invented, these innovation processes need to be carefully and continually monitored and deliberated upon with stakeholders from both science and society.

The second does not relate specifically to the technology of neuroimaging but focuses more on the domain of neuroeducation in general. In this field an important issue in need of further research and deliberation is how local hybrid boundary configurations between research and practice can be set up in a way that, on the one hand help education professionals to make evidence-informed choices, within the context of their own local practice and in line with educational values, and on the other hand contribute to the reflexivity and practice-awareness of neuroeducation researchers. Future transdisciplinary collaborations are just as challenging as they are necessary to establish a responsible embedding of neuroeducation.