SUMMARY

With the aid of new technologies that make it possible to non-invasively study the brain, neuroscience could provide education with a new perspective. **Neuroimaging** and **neurogenomics** contribute to the understanding of normal and abnormal learning and offer possibilities for evidence-based learning and personalized learning. The promises, expectations and concerns regarding possible futures for these emerging technologies shape both research activities and societal debate. They are the entrance point for this thesis, which is about Responsible Research and Innovation (RRI) of neuroimaging and neurogenomics in the domain of education and learning. The research described in this thesis aims to contribute to a proper societal embedding of these technologies by identifying ways to align neuroscience research better with the day-to-day practice of education in schools.

Although developments in the neuroscience field are promising, the application of neuroimaging and neurogenomics to the practice of education is a complicated endeavour, giving rise to different kinds of barriers. First, the technologies used in neuroimaging and neurogenomics are still quite limited, whereas the brain and its development are very complex. Second, the translation from research to everyday practice is not straightforward, and scholars have often written about a “gap” between research and practice. This has lead to questions about what constitutes an effective neuroeducation domain and how such a domain should be created. Third, the application of neuroimaging and genomics technologies in the context of education can give rise to various social and ethical concerns. The assumptions on which a neuroscientifically informed educational enterprise is based are not universally shared. Moreover, the individual application of these technologies gives rise to ethical issues relating to privacy, labelling, stigmatization and possible contributions to inequality, and questions about which actions should be undertaken in light of individual neuroimaging or neurogenomics results. It is important to realize that within society multiple perspectives exist on what desirable futures would be for these technologies within education. There is a clear need to further specify which
opportunities and concerns are considered most relevant by different actors in the domain of learning/education.

RRI departs from reflection on the purpose of technological applications, going beyond the conventional type of ethical review as a way of “closing down” research. Instead, the objective of RRI is to inclusively and democratically define and realize new areas of societal value for innovation. Many scholars have argued that decision-making processes on science and technology should be more participatory and include end users and the public at large. Bringing in a broader range of actors into the innovation process can change the outcome of decisions and thus influence the process of variation and selection of technology. This arguably leads to the development of better, more widely acceptable applications.

Managing real-world complexities

The inclusion of societal stakeholders’ perspectives in innovation is however not an easy task. First of all, the futures of technology of neuroimaging and neurogenomics are uncertain and difficult to anticipate on. Second, the stakes involved are both high and divergent, as many stakeholder views in research and practice need to be considered, with different stakeholders that have their own expertise and deeply rooted values and perspectives. Third, science and technology development take place within bureaucratic structures that are not conducive to a long-term impact of deliberative exercises.

In our research approach to RRI, three issues were taken into account. First, it is possible to manage some of the uncertainty around future applications by examining the guiding visions of neuroimaging and neurogenomics researchers, which give insight into the possible innovation trajectories of these technologies. Second, if decisions with regard to these future applications are to be made in consideration of all stakeholder views, deliberations should allow for the contribution of all those that have a stake in the matter. Their conflicting moral claims warrant careful deliberation. Conflict between stakeholders is often caused by differences in underlying theories and appreciations. These deeper lying ideas determine the way in which stakeholders frame applications of neuroimaging and neurogenomics, or how they make sense of future applications and select the aspects of future visions deemed beneficial or
problematic. If stakeholders’ frames are first made explicit, they can be further deliberated on in a process of frame reflection. Finally, if RRI is to be a sustainable endeavour, it is important that both the structures and the actions contributing to a gap between research and practice are taken into account. One way of examining these structures and actions is by taking a closer look at what is happening at the boundary between neuroscience and educational practice.

Research design

The following main research question was formulated:

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

The Interactive Learning and Action approach (ILA) used provided a general structure for the research but also left room for emergent design. This approach comprised of the following iterative phases: (1) exploration, (2) identification of boundary issues and guiding visions, (3) reflection on guiding visions with a wide variety of stakeholders, and (4) integration of visions through dialogue. The results of these phases are described separately in the different chapters of the book, and will be summarized below.

Neurogenomics scientists’ guiding visions for education

In chapter five the guiding visions of neurogenomics scientists are described. After exploring relevant literature, one focus group and six interviews were conducted with neurogenomics scientists. Although scientists working in different areas of neurogenomics had very diverse ideas about the future of neurogenomics, most of their visions were clinically oriented and focused on applications in health care. The scientists’ different disciplinary backgrounds, empirical practices, overarching theories and moral appreciations contributed to conflicting understandings of key concepts like ‘phenotype’, ‘intelligence’ and ‘environment’. For example, participants using a hypothesis-based approach have a different epistemic view and think differently about the brain that those involved in Genome-Wide Association Studies (GWAS). Researchers’ perspectives regarding the interaction between genes and the
environment have implications for the kind of applications they envision for their research.

Researchers also stay close to their area of methodological expertise during the identification of barriers in the translation of genomic findings into educational practice. During the focus group, the participants discussed the possibility of individual lifestyle advice based on genotype. In order to realize this future, the participants agreed that more insights are needed into the influence of environmental factors. However, the participants had different perceptions of which particular insights were necessary, leading to different research approaches. In particular, perspectives of researchers of early childhood and genomics researchers seem to be far apart. Although the different viewpoints within genomics could be mutually enriching, interactions between disciplines do not frequently occur. More interdisciplinary communication and cooperation is needed before steps can be made in the direction of education. Because neurogenomics research is predominantly oriented towards healthcare and shared visions between researchers were so difficult to identify, it was decided to focus the rest of this research on neuroimaging.

The boundary between neuroscience and education

In **chapter six** the boundary between neuroscience and the practice of education is described. In the literature, much attention has been given to “bridging the gap” between these two fields. In order to gain a better understanding of the nature of this gap and of possibilities to enable the linking process, we have made an analysis of the boundary spanning actors, boundary objects, and boundary work that is being conducted with regard to neuroscience and education. In 26 semi-structured interviews, neuroscientists and education professionals were asked about their perceptions of the gap between science and practice and the role they play in creating, managing and disrupting this boundary.

We have seen that many small bridges are being built between neuroscience and education: books are published for the lay public, research projects are conducted at schools in cooperation with educators and conferences are organized where teachers develop a taste for neuroscience. However, we have also seen that structured and long-term cooperation between neuroscientists and educators does not really take
place. An important finding of this study is that the two parties often hold conflicting views and expectations of both brain-based learning and of each other. The dominant opinion amongst the neuroscientists is that the gap is predominantly about the difference in language used by the two parties. The solution they often provide – neuroscientists should better communicate their findings by involving communication experts – stems from a top-down approach to education and a classical view on science communication. Even though these scientists demonstrate an effort to bridge the gap, it can be argued that this solution actually exacerbates the difference between science and practice, reinforces the boundary between neuroscience and education, and thereby contributes to the gap. Most education professionals hold a different view and argue that scientists should be engaging more with the educational culture and interact more with educational practitioners in order to make the research more relevant to its practice. Education professionals do not speak “normal human language” as they have a professional expertise and language of their own, a point that needs to be recognized by neuroscientists.

Therefore, if neuroscience is to contribute to the complex and value-laden practice of education, it is time to find the middle road between scientific rigor and the more pragmatic approach of the field of education. Instead of bridging the gap in the translation and dissemination of knowledge, it might be useful to think of the integration of knowledge in terms of restructuring knowledge systems, in which different knowledge communities work together in order to develop research questions that are the responsibility of all parties.

**Reflections with societal stakeholders on neuroimaging for education**

**Chapter seven and eight** are about reflections with societal stakeholders on the two kinds of guiding visions described by neuroscience researchers: (1) the application of neuroimaging for personalized learning and (2) for the creation of an ‘evidence base’ for effective learning and teaching. In these two chapters we discuss the results of twenty homogenous focus groups: for both topics we conducted three focus groups with randomly selected parents of one or more children attending secondary school, three focus groups with randomly selected secondary school teachers and four focus groups with secondary school children attending one particular school. Because the focus groups were about different guiding visions they also had a different design.
Summary

However, in both designs the vision for neuroimaging was introduced in a step-by-step manner, starting with a warming up exercise about education, after which the innovation was shortly introduced, followed by a discussion of the opportunities and concerns of the application, and ending with the formulation of conditions under which the application would be acceptable or desirable.

Personalized learning

In discussions about the application of neuroimaging for personalized learning, we identified different value tensions among participants, for example between equality and equity and between freedom and achievement. When the argumentation patterns participants used were analysed in more detail, we found that in some cases it is not simply the values that are at odds with each other. Rather, differences are visible in the way that participants framed the application: which elements were central to their stories, and how these were understood. We have seen that a different framing of ‘the learning child’ and ‘neuroimaging’ can lead to a different attitude towards the application of neuroimaging for personalized learning.

For example, many participants argued that neuroimaging is a reductionist method, but they defined this reductionism in three different ways: (1) neuroimaging is not able to capture the essence of a child, (2) a scan limits children in their freedom and (3) a scan defines intelligence too narrowly. Although reductionism is the main concern in all three cases, the framing of the issue is different. These different framings also lead to different ideas about what desirable applications would be: participants using the first argument saw the application only to be desirable in case of learning problems, participants using the second argument found the application to be entirely undesirable, and participants using the third argument thought that a scan could be best employed to create opportunities for a child by creating insight into their specific talents. These different framings were taken into account in the subsequent structuring of our science-society dialogue.

Neuroimaging as an evidence base

Also with regard to the use of neuroimaging as an evidence base for education, our results show a variety of ways in which evidence from neuroimaging is framed, related to participants’ ideas about the validity of the evidence, considerations about other
types of scientific and non-scientific evidence, and opinions on the importance of basing educational methods on scientific evidence. One result of this study has been that in various respects, neuroimaging was argued by many participants to be no different than other forms of scientific evidence. It is often assumed that education practitioners have a purely positivistic attitude towards neuroimaging in particular, but the focus groups conducted turned out to be an interesting way of exploring ‘ground-level’ philosophy, as the different framings encountered in our analysis coincide with the epistemological notions of positivism, post-positivism, feminism and phenomenology. For many participants, it was not a question of applying either neuroimaging evidence, or psychological research, or the teacher’s or student’s subjective interpretation to education, but of whether or not this knowledge fits within current practice and is in line with their values. Neuroscientific evidence was not perceived to be a magic bullet, and as a measure to guard against hypes, myths, and the negation of an enormous amount of experiential knowledge already embedded in practice, we argue this should and can be reflected more in research and education policy.

**Multi-stakeholder dialogue about neuroimaging for education**

In Chapter nine we discuss the results of the multi-stakeholder dialogue conducted at the end of this research. The deliberative approach that we designed aimed to take into account the uncertainty of technology development and plurality of values and expertise amongst stakeholders. Our dialogue session with teachers, potential intermediary parties, neuroscientists and education scientists took place in three parallel sessions. We started with a frame reflective discussion about the definition of good education, followed by a step-by-step exercise in which each group “reframed” one current societal concern into areas of desirable research. The process of this deliberative exercise was analysed on the basis of the interaction strategies used by participants during situations of frame conflict.

The discussions that took place served as building blocks for an integrated frame for neuroimaging research for education. This integrated frame starts from a broad definition of learning to include, for example, creativity, curiosity, motivation and social processes, and therefore neuroimaging research should pay more attention to these aspects of learning. Neuroimaging researchers should strive to generate general
insights that contribute to learning, as this would be most useful within practice, and research into differences emphasizes these differences. If we want neuroimaging to contribute to personalized learning, this should not refer to an education system in which children learn alone, but to a classroom in which children receive the best education for their needs, which includes learning from others. In order to prevent individualized neuroimaging leading to individualized learning, neuroimaging research into social learning should be put at the top of the research agenda. Furthermore, because the brain is plastic, research subjects should be scanned at different moments in time if we want to be able to say something about learning. However, as the brain is plastic only to a certain extent, the plasticity of the brain should not be used as an argument to stop deliberating how research can be conducted taking into account societal concerns about privacy and discrimination. Finally, neuroimaging is just one of the tools available to researchers, offering one perspective on learning, and neuroimaging findings should be viewed as one part of a complex scientific argument. Therefore, it is important that neuroimaging research is not seen as the golden standard within research, not by educational practice, not by education or neuroscience researchers (and students), nor within policy.

The three dialogue/frame reflection sessions were quite different, and different types of interaction strategies were identified in each group. In the first group, participants were able to construct underlying ideas that could give rise to societal concerns, but the session was less constructive because some of the elements causing fear were not deemed relevant or not taken seriously. In the second group participants employed interaction strategies that lead to the least favourable discursive outcomes, less learning, and some frustration among participants. The outcome of the third group was more favourable, the energy was high and the participants were able to learn from each other’s perspectives. Variants to the process that could have affected the outcome were a different statement, a different member composition, and a different facilitator.

Although the method presented has its caveats, we have shown how a transparent step-by-step process facilitated by an experienced facilitator offers participants a way of untangling some of the complexity encountered when deliberating on desirable future research. By defining and reflecting on which aspects of innovation participants can and cannot connect to and why, reflexive insight is gained by stakeholders into
frame differences but also into frame similarities. In addition, we have seen that this process can facilitate the formulation of ideas for research outside areas of frame conflict, which can contribute to more responsible research and innovation.

**Conclusion**

The steps taken in the different phases have given rise to the following main conclusions:

The research described in this thesis contributes to Responsible Research and Innovation (RRI) 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 their increased awareness of different frames and areas of frame conflict, new ideas for future research and in the formation of new contacts/networks.

The steps taken in this study can be considered to be the beginning of 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.