DISSERTATIONES
PEDAGOGICAE
UNIVERSITATIS
TARTUENSIS
31

MIRJAM BURGET

Making sense of responsible research and innovation in science education

DISSERTATIONES PEDAGOGICAE UNIVERSITATIS TARTUENSIS
31

DISSERTATIONES PEDAGOGICAE UNIVERSITATIS TARTUENSIS
31

MIRJAM BURGET

Making sense of responsible research and innovation in science education

UNIVERSITY OF TARTU
Press

Institute of Education, Faculty of Social Sciences, University of Tartu, Estonia

Dissertation was accepted for the commencement of the degree of Doctor of Philosophy (in Pedagogy) on the 21th of June 2019 by the joint Doctoral Committee of the Institute of Education and Institute of Ecology and Earth Sciences for awarding doctoral degrees in education.

Supervisors: Prof. Margus Pedaste, University of Tartu, Estonia
PhD Emanuele Bardone, University of Tartu, Estonia

Opponent: PhD Ilkka Johannes Ratinen, University of Lapland, Finland

Commencement: White Hall of the University of Tartu Museum, 25 Lossi St., Tartu, 18th November 2019, at 11 a.m.

This study was partially conducted in the context of the European project "Ark of Inquiry: Inquiry Awards for Youth over Europe", funded by the European Union (EU) under the Science in Society (SiS) theme of the 7th Framework Programme (Grant Agreement 612252). This document does not represent the opinion of the EU, and the EU is not responsible for any use that might be made of its content. This study was partially supported by the European Regional Development Fund (DoRa and Doctoral School).

ISSN 1406-1317
ISBN 978-9949-03-197-9 (print)
ISBN 978-9949-03-198-6 (pdf)

University of Tartu Press
www.tyk.ee

Dedication

For my mother
who believed in me more than I ever did

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

CE	–	Citizenship Education
EC	–	European Commission
ELSA	–	Ethical, Legal and Social Aspects of emerging sciences and technologies
EU	–	European Union
IBL	–	Inquiry-based Learning
IBSE	–	Inquiry-based Science Education
NOS	–	Nature of Science
RI	–	Responsible Innovation
RRI	–	Responsible Research and Innovation
R&I	–	Research and Innovation
SSI	–	Socio-scientific Issues
SSIBL	–	Socio-scientific Inquiry-based Learning
TA	–	Technology Assessment

LIST OF PUBLICATIONS

The dissertation is based on the following original publications

I **Burget, M.**, Bardone, E., & Pedaste, M. (2017). Definitions and conceptual dimensions of responsible research and innovation: a literature review. *Science and Engineering Ethics*, *23*(1), 1–19. https//doi.org/10.1007/s11948-016-9782-1

II **Burget, M.**, Bardone, E., Pedaste, M., & Saage, K. (2018). Science teachers' perceptions of the emergence of Responsible Research and Innovation in school. *Journal of Baltic Science Education*, *17*(4), 590−604.

III Bardone, E., **Burget, M.**, Saage, K, & Taaler, M. (2017). Making sense of RRI in science education through inquiry-based learning. Examples from the field. *Science Education International, 28*(4), 293–304.

IV **Burget, M.**, Bardone, E., & Pedaste, M. (n.d.). The RRI Map: Making sense of Responsible Research Innovation in Science Education. *Unpublished Manuscript*.

The author contributed to the publications in the following way:

For paper 1: designing the study, formulating the research questions, planning and carrying out the review procedure and analysis, contributing as the first author

For paper 2: designing the study, formulating the research question, planning and carrying out the data collection and analysis, contributing as the first author

For paper 3: participating in the creation of the study design, participating in the formulation of the research questions, planning and carrying out the data collection and analysis, writing the paper as the second author

For paper 4: participating in the creation of the study design, planning and carrying out the review procedure and analysis, writing the paper as the first author

Related conference papers

Burget, M., Bardone, E., & Pedaste, M. (2016). Dimensions of Responsible Research and Innovation. In L. Gómez Chova, A. López Martínez, I. Candel Torres (Eds.), *Proceedings of INTED2016 Conference: 10th annual International Technology, Education and Development Conference (INTED 2016)* (pp. 1008−1013). Valencia, Spain: IATED Academy.

Pedaste, M., De Vries, B., **Burget, M.**, Bardone, E., Brikker, M., Jaakkola, T., Veermans, K., Siiman, L., Mäeots, M., & Lind, M. (2015). Ark of Inquiry: Responsible Research and Innovation through Computer-based Inquiry Learning. In T. Kojiri, T. Supnithi, Y. Wang, Y.-T. Wu, H. Ogata; W. Chen, S. C. Kong, F. Oiu (Eds.). *Workshop Proceedings of the 23rd International Conference on Computers in Education ICCE 2015* (pp. 187–192). Hangzhou, China: Asia-Pacific Society for Computers in Education.

1. INTRODUCTION

In society today, there is an increasing interest in the significance of research and innovation to address the "grand challenges", e.g. climate change, environmental degradation, social and economic inequalities (Mejlgaard et al., 2018; Ruggiu, 2015; Scholten, van den Hoven, Cuppen, & Flipse, 2016; Tassone, O'Mahony, McKenna, Eppink, & Wals, 2018; Ulnicane, 2016). Citizens with a better understanding of science and technology can actively and responsibly take part in research-based decisions and innovation, and also feel that their voice is heard (Ariza, Abril, Quesada, & García, 2014). Responsible Research and Innovation (RRI) has become more established in recent years and is a potential solution for the "grand challenges", creating opportunities for citizens to actively participate in the research and innovation (R&I) process.

A considerable amount of literature has been produced around the theme of RRI (e.g. De Saille, 2015; Owen, Macnaghten, & Stilgoe, 2012; Ribeiro et al., 2018; Stahl, 2013). Interest has especially grown due to the calls of the project proposals of the European Comission (EC) where RRI is described as a key action to reach the "Science with and for the society" goal (European Commission, 2014). RRI itself is described – in more general terms – by including various actors in society during the early stages in the Research and Innovation (R&I) process so that the outcomes of the process would be the most appropriate for the society (Owen et al., 2012).

Despite increasing interest in RRI during recent decades, RRI suffers from certain ambiguities at a conceptual level. The previous studies indicate that the conception of RRI is still in its infancy (Blok & Lemmens, 2015) or undeveloped (Oftedal, 2014; Reber, 2018; Zwart, Landeweerd, & van Rooij, 2014) and the wide area that RRI covers leads to specialists and researchers making their own interpretation of the concept (Klaassen et al., 2017). Therefore, RRI is missing the theoretical conceptualization as well as the explanation in practice (Owen et al., 2012).

Similarly, the deficiency of the RRI conceptualization emerges in the educational field. The EC has emphasized developing science education as part of RRI so that the education will respond to the needs of the future society (European Commission, 2014). In this connection, various projects and studies are conducted (e.g. Heras & Ruiz-Mallén, 2017; Tassone et al., 2018). However, the previous studies indicate how the EC key of science education is understood in the RRI context, but there is no evidence on how RRI, in theory, should be translated into the practice of science education (Timmermans, 2017).

The studies have shown that the concept of RRI is unclear and not conceptualized meaningfully in educational settings (e.g. Heras & Ruiz-Mallén, 2017). Moreover, although there are studies about the adoption of EC six keys (engagement, science education, gender equality, ethics, open access and governance) in education (de Vocht & Laherto, 2017; Ratinen, Kähkönen, & Lindell, 2018), there is still a deficiency of studies regarding the nature of RRI as it is

stated in scientific literature, and about integrating the RRI concept into education meaningfully. Additionally, the previous RRI-related studies show that the earlier philosophies (e.g. SSI, NOS) in science education are present, but the treatment of philosophies in an RRI context remain fragmented and do not constitute a coherent whole. This study seeks to obtain data which tries to address this research gap.

Only implementing political measures is not deemed as a solution for practicing RRI in education, change is also needed at the grassroots. Nowadays, the need to make learning more relevant or meaningful for learners is apparent (Berland et al., 2016; Chu, Reynolds, Tavares, Notari, & Lee, 2017; Sharan, 2015). Meaningful learning is increasingly more important, getting the answers to how and why something happened rather than merely following the pre-set rules. The current study will try to consider RRI in education more profoundly than the earlier approaches, integrating RRI into the educational system in a way that teachers and learners can make sense of the essence of the RRI in a meaningful way.

One possible way to learn meaningfully is to apply various philosophies (e.g. Inquiry-based Learning (IBL), Socio-scientific Issues (SSI), Nature of Science (NOS), Socio-scientific Inquiry-based learning (SSIBL) in schools. Until now, these philosophies have been implemented in various aspects, e.g. including different parties in the learning process, an enhancement of meaningful or democratic learning (Akinsanya & Williams, 2004; Laherto et al., 2018; Maass, Doorman, Jonker, & Wijers, 2019; van Uum, Verhoeff, & Peeters, 2017), and these aspects are also important in the context of RRI. Developing RRI in science education also provides a valuable opportunity to develop these philosophies. Moreover, concerning RRI as part of various philosophies would improve the existing philosophies and ensure more meaningful learning.

Taking the latter into account, the aims of the present research were to determine:

- the definitions and conceptual dimensions of RRI based on the relevant literature on the topic.
- how science teachers perceive the emergence of responsible research and innovation in their work.
- a better understanding of the meaning that the term responsibility can have in different phases of inquiry-based learning.
- the complementarity of RRI-related philosophies in science education and to consider responsibility as a part of the RRI-related philosophies in science education.

This research seeks to address the following questions:

- How is RRI defined in academic literature and how have the conceptual dimensions of RRI emerged and been discussed in the academic literature?
- How science teachers perceive the emergence of responsible research and innovation in their work?

- What is the meaning that the term of responsibility acquires during different phases of inquiry-based learning?
- How the philosophies previously appearing in RRI-related science education can be described comlementarily and how the responsibility appears as part of the philosophies?

The studies started in the context of the Ark of Inquiry project (http://www.arkofinquiry.eu), its purpose to increase youth awareness of RRI as well as to promote responsible and scientifically literate society through Inquiry-based Science Education (IBSE). Three research papers were published considering the project: RRI through computer-based inquiry learning (Pedaste et al., 2015); considering the current dissertation, the second study (Burget, Bardone, Pedaste, & Saage, 2018) and third study (Bardone, Burget, Saage, & Taaler, 2017). The first study (Burget, Bardone, & Pedaste, 2017) and fourth study (Burget, Bardone, & Pedaste, n.d.) were carried out beyond the project. It should be noted that the answer to the first research question is presented in the literature review of the current dissertation, the answer for the II–IV research questions can be found from the findings.

This research is carried out to contribute to a deeper and more coherent understanding of RRI, hopefully improving the conception of RRI which has been previously treated in education in a fragmented way. The findings should make an important contribution to the field of education by proposing ways how to meaningfully integrate RRI into science education more in line with the today's education needs.

The overall structure of the dissertation takes the form of six chapters, including this introductory chapter. Chapter two begins by laying out the literature review and explains the historical roots of RRI, responsibility as an essential element of RRI, and the conceptualization of RRI in science education. The third chapter is concerned with the methodology and rationale of the current dissertation. The fourth section presents the findings of the research, focusing on the four key categories that emerged: *sense-making*, *action-taking*, *exploring* and *inclusion*, and the RRI model in science education which summarizes the mentioned categories in the light of the philosophies in science education. The discussion draws upon the entire dissertation, bringing together the various theoretical and empirical strands. Finally, the conclusion gives a brief summary of the findings, including at the same time recommendations for practice and policy, significant issues for the future research, and implications of the findings.

2. LITERATURE REVIEW

2.1 The historical roots of RRI

Although the term RRI was originally coined in European Union (EU) documents, its evolution started already before the conception was formulated in its current form. For the formulation of RRI, the approaches and conceptions, e.g. sustainable development; Technology Assessment (TA); Ethical, Legal and Social Aspects of emerging sciences and technologies (ELSA); and anticipatory governance played a vital role (e.g. Grunwald, 2009; Guston & Sarewitz, 2002; Tassone et al., 2018; Zwart et al., 2014). The initial meaning of RRI was introduced in the EC 6th Framework Programme as the "responsible use of scientific and technological progress" (European Commission, 2002). The term "Responsible Research and Innovation" as it stands now was first mentioned in the EC's 7th Framework Programme (European Parliament, 2013). The RRI in the EC's 7th Framework programme was reflected as an opportunity where science and society work together to enhance public trust in science (the more detailed review of the establishment of RRI can be found from the first study).

Since the formulation of the concept of RRI by the EU, various research development projects have been elaborated by the Horizon 2020 program (e.g. Ark of Inquiry, RRI-ICT Forum Project, HEIRRI Project, RRI Tools, PARRISE Project). The Journal of Responsible Innovation in 2014 (Timmermans, 2017) has been at the forefront of widely elaborating the concept in academic publications. The concept of RRI in academic discourse contains different features which describe the nature of RRI and can be named as the RRI dimensions. The RRI definitions and dimensions are described more in detail during the next chapters.

2.2 Definitions and conceptual dimensions of RRI

2.2.1 The definitions of RRI

As mentioned in the previous chapter, the term RRI was originally identified in science policy by the EU in a top-down way (Zwart et al., 2014). Together with RRI, the conception of RI (Responsible Innovation) has evolved (Owen et al., 2013; Stilgoe, Owen, & Macnaghten, 2013). However, the studies have shown that these two conceptions are used interchangeably (Asveld & van Dam-Mieras, 2017; Fisher & Rip, 2013). RRI is also described as an umbrella term which comprises the existing practices and theories (Fisher & Rip, 2013; Owen et al., 2012; Timmermans, 2017).

Ruggiu (2015) in his study, distinguishes between two versions of RRI: the normative, and the socio-empirical. Similarly, in the current dissertation two types of RRI are distinguished, but named as the *administrative* which includes

the definitions from policy makers and funding agencies (de Bakker, de Lauwere, Hoes, & Beekman, 2014) and the *academic* which encompasses the definitions derived from the academic world. The academic definitions embrace the academic contributions that are published in academic journals and which aim was to promote the conception of RRI. In the following chapters, the administrative and academic definitions are described (a more detailed description is available in the first paper).

2.2.1.1 Administrative definitions

One of the earliest definitions of RRI was derived by Sutcliffe (2011) where the author emphasized (1) the focus on R&I to gain a social and environmental advantage, (2) the constant involvement of society from the beginning to end of the R&I process (3) evaluating and prioritizing the social, ethical and environmental aspects together with technical and commercial, (4) taking into account the problems or opportunities and also a readiness to respond to the changing circumstances, (5) paying attention to openness and transparency as important aspects in the R&I process.

Similarly, von Schomberg (2011, p. 9) provides his definition for RRI as follows:

> *Responsible Research and Innovation is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view on 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).*

Von Schomberg's definition is the most commonly used definition in research literature. However, von Schomberg's definition is criticized by Davis and Laas (2014) who mentioned five shortcomings of the definition, namely (1) concentration rather on "innovation process" and "marketable products" rather than "knowledge"; (2) offering no definition for "innovation", (3) a difficulty in understanding why RRI should always lead to "marketable products", (4) providing societal desirability as a separate category and (5) the uncertainty of the words "in our society". Later, von Schomberg (2013) developed his definition further, describing RRI as the *design strategy* which leads to the "marketable products". This makes it plain that RRI is seen as a "process" which leads to the research, products or service (Jacob et al., 2013). In conclusion, the aspects that the administrative definitions emphasize are participatory governance, inclusion, anticipation, adaption and attention to the societal, ethical and environmental aspects together with the technical and commercial.

2.2.1.2 Academic definitions

In academic literature, various ways to define RRI exist. Stilgoe with colleagues (2013, p. 1570) bring in a broader treatment of the definition describing RI as:

> *taking care of the future through collective stewardship of science and innovation in the present.*

In Stilgoe et al., (2013) vision four RRI dimensions appear, namely anticipation, inclusion, reflexivity and responsiveness. As shown, the authors have, for the first time, paid attention the responsibility as care.

In academic definitions, the public engagement appears clearly, therefore RRI is also named as the "collective experiment of democracy" (Klaassen et al., 2017, p. 90). The societal desires and democratic viewpoint is also clearly pointed out in Stahl's (2013, p. 5) definition where he describes RRI as:

> *a higher-level responsibility or meta-responsibility that aims to shape, maintain, develop, coordinate and align existing and novel research and innovation-related processes, actors and responsibilities with a view to ensuring desirable and acceptable research outcomes.*

Wilford (2016, p. 348) gets more concrete concerning the personal desirability of RRI:

> *RRI creates a step-change in the way that those who are engaged in research and innovation should consider the impact of what they do.*

Wilford's definition is remarkable as it takes into consideration the personal responsibility in the R&I process that has not emerged this way in earlier studies.

In conclusion, RRI is seen in academic discussion as the process of including various stakeholders, reflecting, anticipating and responding to the values and needs of society. The other aspects and dimensions which characterize RRI include desirability, acceptability and innovation which were used in academic definitions occasionally. The academic dimensions also emphasize the outcomes of the R&I process and includes various standpoints from society.

Taking together the earlier discussion, RRI is described as

> *an attempt to govern the process of research and innovation with the aim of democratically including, early on, all parties concerned in anticipating and discerning how research and innovation can or may benefit society* (Burget et al., 2017, p. 9).

Here anticipation means describing the way the results of research can be estimated in the future. Discerning denotes that people should judge if the future is something that they "imagined" and act according to it.

2.2.2 The RRI dimensions

The current chapter briefly describes the conceptual dimensions of RRI and RI which are important to characterize the general framework of RRI (Stilgoe et al., 2013) and to understand the profoundness of the concept. The term "dimension" is also used as "feature", "approach", "key" or "aspect" in the RRI-related studies.

In research literature, various authors have attempted to conceptualize RRI and thus different RRI dimensions are described. The first attempt to conceptualize RRI came from Owen et al., (2012) who have listed dimensions as democratic governance, responsiveness and responsibility. Klaassen et al., (2017) proposed the RRI dimensions as purpose, products, processes, preconditions and people, whereas Stahl (2013) has concentrated on the more practical side of RRI empathizing actors, norms and activities. Stilgoe et al. (2013) and Setiawan and Singh (2015) have stressed the dimensions that appeared during the public debates, namely anticipation, inclusion, reflexivity and responsiveness. However, despite the previous dimensions that have appeared in academic literature, the EC has highlighted the six keys, namely engagement, science education, gender equality, ethics, open access and governance (European Parliament, 2013). In addition to the directly RRI-related dimensions, the adjacent dimensions, which were initially not associated with RRI, are considered in research literature, e.g. liability, accountability, care and responsiveness (Pellizzoni, 2004).

For the current literature overview, the RRI dimensions proposed by Stilgoe et al., (2013) are taken into account, additionally two emerging conceptual dimensions are added, namely sustainability and care. In the next chapters a short overview of the referenced dimensions is given.

2.2.2.1 Reflexivity

Reflexivity means that participants of the R&I process reflect the probable futures, values, perspectives, needs, choices and interests, rephrase the problems and share the responsibilities in the R&I process (Stilgoe et al., 2013). Reflexivity is described as a meaning-making process (Rodgers, 2002), a tool which helps to consider the socio-ethical or socio-economic aspects (Flipse & Bayram-Jacobs, 2016; Flipse, van der Sanden, & Osseweijer, 2013); the reflection which emerges with interaction with others (Rodgers, 2002; Setiawan & Singh, 2015) or analysis of the current situation and background of the R&I (Kupper, Klaassen, Rijnen, Vermeulen, & Broerse, 2015).

Reflexivity can be seen from the different angles: the first-order reflexivity which comprises individuals and their relations to the technology and second-order reflexivity comprising the collective social responsibility about the technology (Herkert, 2005). Van der Horst (2018) emphasizes that when we are taking into account the science, the micro-ethics concerns the way the experiment is done, whereas the macro-ethics comprise the greater ethical questions, e.g. decisions which take into account the ethical side. Therefore, reflexivity itself comprises of both broad and narrow aspects.

Reflexivity is also a basis for public discussion (Flipse et al., 2013). For example, Wilsdon (2005) has emphasized the need for involving the public in the R&I process, which also helps researchers to reflect the social and ethical side of their work. The public can also discuss the social and ethical side of science when the public is involved in the laboratory processes (Stilgoe et al., 2013). The other aspect which is also often connected to reflexivity is anticipation, which helps to avoid the wrong predictions during early stages of technological development (Robinson, 2009). To conclude, reflexivity encompasses reflection, meaning-making and public dialogue in society, but also anticipation of the ways in which science and technology may influence society.

2.2.2.2 Responsiveness

The dimension responsiveness is characterized by the emphasis on the responsiveness to the emerging problems, but also the opportunities when they appear, instead of paying attention to the outcomes (Bardone & Lind, 2016). Comparing to the other dimensions, responsiveness is less prevalent in RRI-related research articles. The discussions that evolved in such articles included risks, ethics, transparency and accessibility (Forsberg et al., 2015; Frewer et al., 2014; Levidow & Neubauer, 2014; Stilgoe et al., 2013).

Responsiveness is additionally seen from the action-taking perspective. Here, for example, Kera (2014, p. 7) has shown that the importance of "Do it yourself" science should be increased so that citizens, together with scientists, undertake the activities in order to explore together. Thus, through the conversations and teamwork citizens start to notice the ethical, environmental, governance or aesthetic topics around them (Ferguson, 2011). This may be considered as a community-building task where citizens can take responsibility to solve the problems. Overall, responsiveness is a dimension comprising the active side, paying at the same time attention to ethics, risks, and transparency during the RRI process.

2.2.2.3 Inclusion

Inclusion, engagement and participation are the core concepts in different RRI-related research sources (Timmermans, 2017). The aim of inclusion is to include different stakeholders at early stages of the R&I process (Asante, Owen, & Williamson, 2014; De Saille, 2015; Ferri et al., 2018; Majorek & du Vall, 2018; Timmermans, 2017; van der Meij, Broerse, & Kupper, 2017) and thus inclusion is described as a way of making sense about science with and for society (Asveld & van Dam-Mieras, 2017; Klaassen et al., 2017). Inclusion is also deemed as a way to change the politics when opinion of various stakeholders is taken into account (Heras & Ruiz-Mallén, 2017).

For better functioning of inclusion, various methods and techniques are used. Many authors have shown the way of deliberate inclusion and how the process

should be carried out. Here, for example, van der Meij et al., (2017) has emphasized the role of discussion and reflection in the R&I process where R&I practitioners get acquainted with the view of citizens and take them into account in R&I practices. This is a process where all participants became familiar with their and other people's view in R&I practice which – in the end − can influence their attempt to change one's attitude (van der Meij et al., 2017). Inclusion also comprises stakeholders in dialogue, attempt to share the power, trying to be open and respectful for others (Abma & Broerse, 2010; Chilvers, 2013). The other techniques and methods of inclusion comprise citizen juries and panels, focus groups, consensus conferences, science shops (Chilvers, 2010). Additionally, technological devices where people are given their say are emphasized in RRI-related inclusion (Vasen, 2017). Together, these studies outline that inclusion comprises involvement of various parties at the early stages in order to reach the possible suitable output and by facilitating the cooperation process by various methods.

2.2.2.4 Anticipation

Similarly to inclusion, anticipation is referred to in research literature by the responsible side of RRI (Timmermans, 2017). Anticipation is often connected to governance and is referred in a variety of sources, with a range of technical considerations to environmental and political deliberation (Roco, Harthorn, Guston, & Shapira, 2011; Stilgoe et al., 2013; Stirling, 2010; Te Kulve & Rip, 2011). Anticipation means understanding how the RRI dynamics can shape the future, trying to see the probable impacts of the research to the R&I futures, reflecting different possible problems, but also values, beliefs and assumptions in society (Grinbaum & Groves, 2013; Owen et al., 2012). Therefore, anticipation is characterized as

> *describing and analysing those intended and potentially unintended impacts that might arise, be these economic, social, environmental or otherwise*

where it is important to note that anticipation is not a mere prediction of future (Owen et al., 2012, p. 38).

Similarly to inclusion, the dimension of anticipation emphasizes the provision in early stages. For example, Stirling (2010) has stressed that negative impacts of products or services should be considered at the beginning of the process, so that the possible negative sides are taken into account at the earliest stages. In summary, the anticipation includes understanding the probable future impacts of the R&I process including various stakeholders at early stages.

2.2.2.5 Sustainability

Sustainability is considered as an emerging conceptual framework in the RRI context which denotes creating and preserving the conditions under which humans and nature can exist in harmony and which allow fulfilling the social, economic and other demands for present and future generations (Keeble, 1988). In RRI-related articles the sustainability is not explicitly considered as a dimension. The concept is used by those researchers who have used von Schomberg's definition in their studies (e.g. Bozeman, Rimes, & Youtie, 2015; Stahl, 2013), but also those who have used it without the reference to this definition (e.g. Bremer, Millar, Wright, & Kaiser, 2015; De Martino, Errichiello, Marasco, & Morvillo, 2013; Flipse et al., 2013).

Sustainability refers to the resource efficiency: using sources in an unsustainable way is the main problem the techno-scientific innovation should face (Levidow & Neubauer, 2014). Flipse et al., (2013) supports the idea that R&I should be connected to the social responsibility and in this way it is possible to produce more sustainable products. Although sustainability is not a large factor in academic literature in connection with RRI, the concept needs further studies in the future. Particularly for the reason that the dimension of sustainability in RRI context is not well established.

2.2.2.6 Care

Responsibility as care is considered as something a human can actively take. For example, care is concerned with a part of the public domain whereby people, by themselves, take responsibility for the actions that they want to carry out (Adam, 2008). Thus, care is seen as a way people can take responsibility, rather than just following the set of rules. Although care is not explicitly considered as a dimension of RRI, its emergence can be seen in various studies (Pavie, 2017; Stilgoe et al., 2013; Tassone et al., 2018). The dimension of care is described in more detail in paragraph 2.3.

2.3 Responsibility as the essence of RRI

Concerning the RRI, it is important to talk about responsibility, because responsibility distinguishes RRI from its predecessors (Timmermans, 2017). The report of EC (Hazelkorn et al., 2015) states that science teachers and educators have a responsibility to adopt the concept of RRI. Although the EC report concentrates on the responsibility of embedding RRI in science education, the importance of responsibility is additionally emphasized by other authors. For instance, Laherto et al., (2018) adds that there is a strong likelihood that the notion of responsibility will be at the core of European science education in the coming years.

Turning now to responsibility in general, Van de Poel & Sand (2018) divide responsibility into two parts: descriptive and normative. The descriptive meaning of responsibility entails the "responsibility with cause" (p. 4). This type of responsibility can be compared to "accountability" or "liability" (Adam & Groves, 2011; Bardone & Lind, 2016; Bivins, 2006; Cook-Sather, 2010; Gianni, 2018; Tassone et al., 2018; van de Poel & Sand, 2018). Although the term "accountability" is widely elaborated in educational policy, sociology and history (e.g. Schedler, 1999; Vasquez Heilig, Ward, Weisman, & Cole, 2014), defining the concept in this sense is not the priority of the current dissertation. However, the term responsibility as "accountability" means here the triadic relation which encompasses a person who is responsible to a third party in order to complete a task to reach a specific result (Lucas, 1995, p. 185). From the educational perspective, responsibility as accountability means that learners are in charge of something and should follow the orders given by the school administration or teachers (Cook-Sather, 2010). This type of responsibility concentrates on the responsibility as the outcome of a process (Bardone & Lind, 2016). However, being in charge of something may remove learners from their inner desire to discover and learn and they may lose contact with the ambiguity and complexity of the world (Biesta, 2015).

The normative type of responsibility is further subdivided into two classes, namely evaluation of an action concerning merit of blame, and an obligation to commit something or to take care (van de Poel & Sand, 2018). It must be noted that "care" should be seen as a fundamental part of RRI in education, partly also because the nature of RRI refers to the process which is open to the future and not pre-determined in advance. This type of responsibility is also called as the process-oriented responsibility (Bardone & Lind, 2016). However, "care" also has a different meaning – concerning e.g. the early childhood education (Urban, Vandenbroeck, Laere, Lazzari, & Peeters, 2012) concentrating only on relationships of the "caring" and "cared-for" (Noddings, 2006). However, defining the concept in this sense is not the priority of the dissertation. The conception "care" is addressed as the activity where both thinking and acting are concerned and exists in accordance with the public norms and values (Ruddick, 1995).

The virtue of responsibility is considered particularly significant in the context of RRI (van de Poel & Sand, 2018) which also corresponds to the definition of "taking care of the future through collective stewardship of science and innovation in the present" (Stilgoe et al., 2013, p. 1570). Responsibility here is seen from the individual perspective, considering responsibility as phronesis or a sense of care (Bardone & Lind, 2016; Costello, 2019; Mejlgaard et al., 2018). Phronesis is a concept from Aristotle, referring to practical wisdom, ethics or administrative competence, taking into account the specific situation and considering a number of alternatives in order to take decisions which correspond best with a human or the whole society (Mejlgaard et al., 2018).

In education, "care" may mean that learners should be given more freedom to formulate their own views and opinions (Hodson, 2014). Learners should be seen as active participants, rather than the actors over whom the actions are taken

(Cook-Sather, 2010). Participating in a process means a meaningful engagement of the learners. So it rests on the teacher to give learners more opportunities to take the responsibility and teachers by themselves can't assume that learners can take responsibility by themselves. Responsibility in this context is more process-based than outcome-based, allowing learners to take the ownership and ensuring they are meaningfully engaged in the process.

Thus, it can be said that today's society needs humans who act responsibly and are mindful of the problems in the world. The growth of responsible citizens depends on the nature of education. Thus, responsibility as care should be deemed as a valuable part of raising the humans for the future society.

2.4 RRI in science education

The concept of RRI has been linked with school curriculum development and EC six keys or discussed in education in connection with the previous philosophies. The following sections provide an overview of the ways for integrating RRI into education.

2.4.1 Emergence of RRI and its dimensions in school curriculum

The attempts have been made to develop RRI in the school curriculum in Europe. However, it has emerged that RRI is moderately included in school curriculums in Europe (Kearney, 2016) yet there is not much knowledge about how, considering the curriculum, the innovative and active future citizens should be educated (Buckley, Tassone, & Eppink, 2016; Heras & Ruiz-Mallén, 2017; Mejlgaard et al., 2018; Tassone et al., 2018). Efforts are being made in some systems in Europe where teachers, for example, can get extra credit if they integrate RRI into their practice (Laherto et al., 2018).

In research literature, various ways are proposed to embed RRI into the school curriculum. It has been suggested that curriculum should not only include academic skills (the basic skills that are part of the school curriculum) and operational skills (the skills that help to operate in the digital world), but also the skills that are essential in real-life, e.g. carried out in complex real-life situations. This leads to educating the whole person and developing the skills that foster responsiveness and care towards societal challenges (Tassone et al., 2018). The curriculum should also include the interdisciplinarity or – in other words – how the research learners conduct is connected to other domains (Nulli and Stahl, 2018). The interdisciplinarity is closely linked to the combination of hard and soft sciences, which several authors describe as one of the main characteristics of RRI (Felt, 2014; Ribeiro, Smith, & Millar, 2017).

Integrating RRI into the curriculum has raised the issue about the way RRI should be taught: implicitly or explicitly (de Vocht & Laherto, 2017; de Vocht, Laherto, & Parchmann, 2014; Laherto et al., 2018). Explicitly here means that

learners should know what RRI according to the EU concept means, implicitly denotes that RRI should be taught in the context of other concepts and not referring to the concept of RRI directly. As presented, there are various solutions available to integrate RRI into curriculum, but concurrently the deficiency of any clear guidance is the main obstacle.

Turning now attention to the Estonian curriculum, the notion of responsibility, but also RRI-related themes can be identified. At first it should be mentioned that the basic school grades are divided into the stages, namely: (1) first stage of study (grades 1−3), (2) second stage of study (grades 4−6), and (3) third stage of study (grades 7−9; (National curriculum for basic school, 2011) and upper secondary school which is treated separately (National curriculum for upper secondary schools, 2011).

In the Estonian national curriculum, for basic and upper secondary schools, the notion of responsibility is widely referred (National curriculum for basic school, 2011; National curriculum for upper secondary schools, 2011). The responsibility appears in the key points of the social values, general competences (e.g. social and civic competence and entrepreneurial competence) and developing the mental and social environment. Responsibility itself as the objective in education first appears in the second stage of studies, where learners are expected to become independent and responsible citizens. In the third stage of studies, learners are expected to be responsible members of society who are able to independently manage their lives. The science syllabus in basic and upper secondary school (including the subjects of biology, chemistry, physics and geography) emphasizes decision-making on socio-scientific issues, valuing a sustainable and responsible lifestyle as well as collaboration, and also emphasizing various methods also described in an RRI context (e.g. discussion, debates, research-related work). Teachers' responsibility has been highlighted in Estonian teachers' professional standards ("Teacher's professional standard," 2019), where responsibility is mentioned as the human characteristic necessary for the teaching profession.

Although the notion of responsibility is described widely in the national curriculums and partly referred to in the Estonian teachers' professional standard, the meaning of responsibility still remains unclear. Moreover, the philosophies that have a solid base in science education, are addressed in a fragmented way and their meaning is ambiguous.

2.4.2 RRI in existing philosophies in science education

Taking into account the RRI-related research and development projects (e.g., Ark of Inquiry, PARRISE, IRRESISTIBLE) and academic literature, attempts to connect RRI to the philosophies have been tried. Based on the literature review, the next paragraphs describe briefly the most visible RRI-related philosophies in science education, namely SSI, IBL, NOS and CS. The name "philosophy" is also used to characterize SSI, IBL, NOS and CE in the academic literature (e.g. Cartieri & Potochnik, 2014; Harré, 1985; Levinson & Consortium, 2017;

Spronken-Smith, Walker, Batchelor, O'Steen, & Angelo, 2011). Although SSI is the most pronounced philosophy connected with RRI in research literature, the importance of being attached to the philosophies IBL, NOS and CS should also be considered. All philosophies have been described as characterizing the main aspects of RRI and are the most referenced in academic literature (García-Carmona & Acevedo-Díaz, 2018; Hadjichambis et al., 2018). In the next chapters, the philosophies and their connections to RRI are briefly described, based on the academic literature (more specifically in fourth article).

2.4.2.1 Inquiry-based learning

IBL can be characterized as a way where students have the opportunity to experience getting into contact with something that the real scientists do and in this way producing new knowledge (Anastopoulou et al., 2012; Kaberman & Dori, 2009; Kazempour, 2009; Kirch, 2010; Pedaste et al., 2015; Trilling & Fadel, 2009; Van Joolingen, De Jong, & Dimitrakopoulou, 2007; Wang & Lin, 2008). IBL is defined as "a process of discovering new causal relations, with the learner formulating hypotheses and testing them by conducting experiments and/or making observations" (Mäeots, 2014, p. 15). IBL is characterized by phases, in particular orientation, conceptualization, investigation, conclusion, and discussion (Figure 1; Pedaste et al., 2015). In passing through the phases students have to define the problem, pose the research question or elaborate hypotheses, design and perform experiments, draw conclusions from the data and communicate the findings.

The literature that concerns RRI and IBL emphasizes the knowledge, skills and values which means for instance, the learners becoming scientifically literate, making sense of the science and the results for society by means of the IBL process (Ariza et al., 2014; Okada, Kowalski, Kirner, & Torres, 2019; Okada & Sherborne, 2018). However, the studies have presented the challenges for science teachers to connect IBL- and RRI-related educational activities (Ratinen et al., 2018; Stavrou, Michailidi, & Sgouros, 2018). As the RRI concept is hard to understand for learners, the development of new approaches to RRI teaching with various parties (e.g. teachers, educators, researchers) has been provided as the solution (Ratinen et al., 2018).

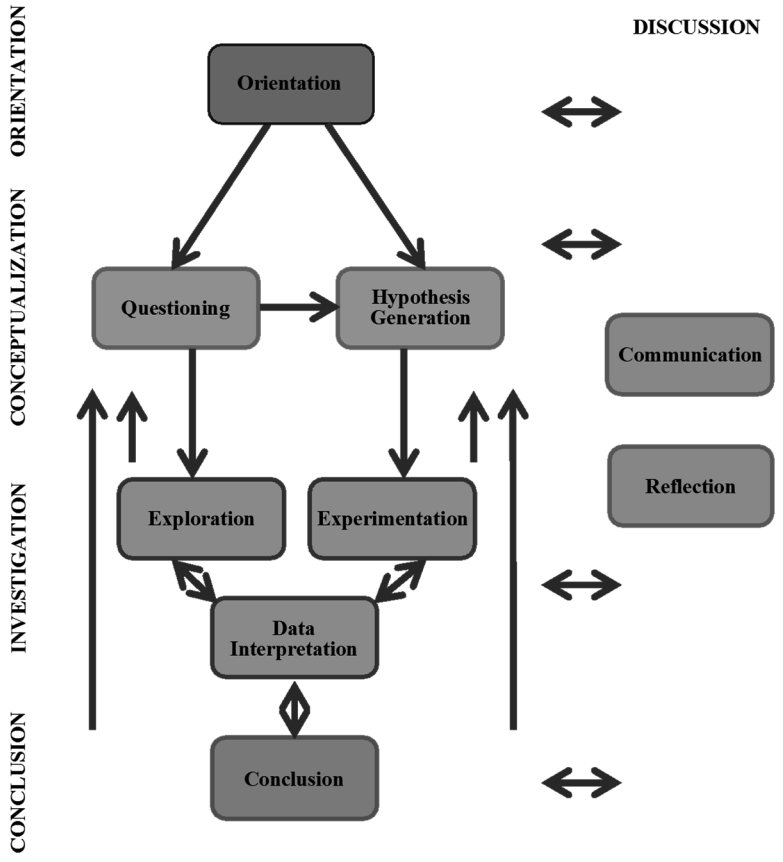

Figure 1. The IBL framework (Pedaste et al., 2015)

2.4.2.2 Nature of Science

NOS is described as an attempt to get a wide-ranging understanding of the nature of the scientific enterprise (Abd-El-Khalick, Bell, & Lederman, 1998; Lederman & Zeidler, 1987). Although it is difficult to define what the scientific enterprise is, the researchers are agreed on the following principles: scientific knowledge is uncertain, partly creative, based on the experimental evidence and is situated in the cultural and social milieu (Abd-El-Khalick, 2006; Dagher & Erduran, 2016; McComas, Clough, & Almazroa, 1998).

Recently, various studies have been published concerning NOS and RRI (e.g. Heras & Ruiz-Mallén, 2017; Laherto et al., 2018; Lundström, Sjöström, & Hasslöf, 2017; Ratinen et al., 2018; Tirre, Kampschulte, Thoma, Höffler, & Parchmann, 2018). In the studies, the nature and the role of science in society is emphasized (Ratinen et al., 2018). Heras and Ruiz-Mallén (2017) approach the RRI and NOS connection somehow narrowly emphasizing the RRI dimension – RRI values and

ethical issues – as the dimension connected to NOS. More recently the "modern" type of NOS has appeared which is interdisciplinary and means to include different parties, and take into account the social values and politics (Laherto et al., 2018).

2.4.2.3 Socio-scientific issues

SSI is the philosophy that concentrates on the controversial issues in society containing at the same time an ethical component, and are associated with the science (Zeidler & Nichols, 2009). Such issues demand the application of scientific reasoning, are complex in nature, and include moral and ethical component (Sadler, Chambers, & Zeidler, 2004). The SSI and RRI connection appears in bringing the RRI aspects to curriculum and therefore the social aspects of science as well as the growth of the active citizens highlighted (Evagorou & Mauriz, 2017; Hadjichambis et al., 2018). The other aspects of RRI and SSI are the ethical, sustainable and socially acceptable development in science and technology, simultaneously addressing democracy, reflexivity, transparency, anticipation and inclusiveness (Evagorou & Mauriz, 2017; Hadjichambis et al., 2018; Lundström et al., 2017).

2.4.2.4 Citizenship Education

CE is characterised as enhancing learners' political, legal and economic knowledge of the social coherence (Gifford & Gomez, 2014; Sincer, Severiens, & Volman, 2019). One part of the CE philosophy is also the public action-taking (Geboers, Geijsel, Admiraal, & Dam, 2013; Gifford & Gomez, 2014; Schulz et al., 2016; Sperling, Wilkinson, & Bencze, 2014). CE philosophy in the studies where RRI is concerned is developed to a minor degree. The studies emphasize the moral and social side of the society and learning the skills that are needed in a multi-cultural and democratic European society. CE is regarded by the critical-democratic citizenship which takes into account the democratic, reflective and dialogical learning (Ariza et al., 2014; Maass et al., 2019).

2.4.2.5 Socio-Scientific Inquiry-based Learning

In the current dissertation, attention is also paid to the SSIBL philosophy, elaborated in the light of RRI, and considered as a hybrid philosophy (e.g. Levinson & Consortium, 2017; Verhoeff, 2017). The basic idea of SSIBL is embedded in critical citizenship education, including at the same time IBL and socio-political issues. In practice this means the youngsters can research a topic relevant for them in order to improve both local and global issues, to approach results via the democratic processes which may include concurrently the action-taking approach. The process in general is grounded in the contextualized scientific knowledge (Levinson & Consortium, 2017).

The SSIBL philosophy itself is described by dimensions. Verhoeff (2017) describes the four dimensions, namely (1) knowing about the topic, (2) skills to identify the socio-scientific-based inquiry, (3) values of the social justice and wellbeing, and (4) inclusion and democratic deliberation. Romero-Ariza et al (2017) highlights three dimensions, (1) authenticity, (2) controversy and (3) action-taking. The dimensions characterize the nature of RRI and the way RRI can be approached in an educational context.

3. METHODOLOGY

The methodology of the dissertation has been organized by introducing the research design, sample, data collection, data analysis, trustworthiness of the study, and researcher's reflexivity.

3.1 Research design

Taking into account the formulated research questions, the dissertation is based on four studies. The research design (Figure 2) represents the three studies.

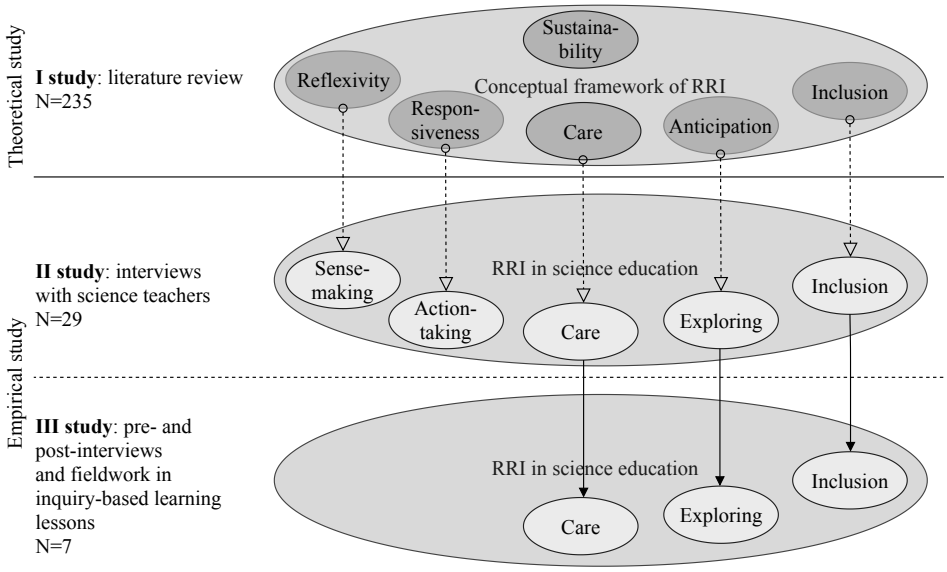

Figure 2. Research design (the arrows with dotted patterns show that the meaning of the dimensions is adapted to the educational field; the straight line arrows show that the meaning of the dimensions is taken into consideration as it was stated in the previous study).

The literature review was conducted at first (first study) to explain the nature of RRI by describing the definitions and dimensions of RRI (Burget et al., 2017). Secondly, the nature of RRI was considered necessary to be adapted to the educational field. Hence, two empirical studies were carried out (second and third study; Bardone et al., 2017; Burget et al., 2018). Eventually, the theoretical study was carried out with the aim of explaining the meaning of RRI in science education by providing the comprehensive view including different philosophies (Burget et al., n.d.).

The study as a whole is exploratory, established with the aim of developing understanding of a little-explored area (Creswell, 1998). Qualitative methods are

used in the current dissertation to offer an effective way of analyzing the multifaceted social phenomena (Denzin & Lincoln, 2017; Silverman, 2013). Qualitative methods are useful for providing a comprehensive and rich description, the possibility to gather data about the holistic human experience in a natural environment, and to study the informants' inner practice to see how their understandings are formed (Rahman, 2017). In the next paragraphs, a detailed description of the **second and third study** is provided.

3.1.1 Sample

In the **second and third study,** altogether 36 science teachers aged between 24 and 54 years participated, their continuity of service was 1–35 years (an average of 16 years). There were 29 women and eight men who participated. Teachers taught in grades 1^{st} −12^{th} (learners aged 7−19).

In both studies, the sample was deliberately comprised of science teachers in Estonian basic, upper secondary and extracurricular schools. The sample comprised of as wide experience as possible which also ensured the rich dataset. There were 24 basic school teachers (learners aged 7−15), six upper secondary school teachers (learners aged 16−19), two teachers who taught both in basic and upper secondary school and four teachers who taught in extracurricular school (learners aged 7−19). The subjects included biology, physics, chemistry, geography, science, human studies, robotics, basics of research and environmental studies.

The informants were recruited by snowball and convenience sampling. The author of the current dissertation included her acquaintances who responded to the criteria of sampling (see also 3.1.4.1), but also the teachers who participated in projects at the University of Tartu where the author of the dissertation is working. Additionally, those teachers were included whose schools were situated nearby the university where the study was conducted. The informants were recruited by e-mail, Facebook messenger, telephone or face-to-face. The sampling in both studies was based on theoretical saturation: the data was collected until the saturation point was reached. That means the new information found did not add anything new to the general data (Corbin & Strauss, 2014).

As for the ethical considerations, the informants in both studies took part voluntarily. Before the interview, the interviewer explained the ethical aspects to the informants. Written permission was asked from parents whose children were observed (e.g. containing anonymity, voluntariness to participate in the study and data protection). The study was also introduced to the learners before the data collection. For example, in our study some learners did not want to be in any pictures and this was taken into account when conducting the fieldwork.

3.1.2 Data collection

As stated earlier, the **second study** was based on the interviews with 29 science teachers and the **third study** was based on the pre-interviews, observations on the field and post-interviews with seven science teachers. The pre- and post-fieldwork interviews were considered as background information for the fieldwork observations. The figure 3 shows the timeline of both studies.

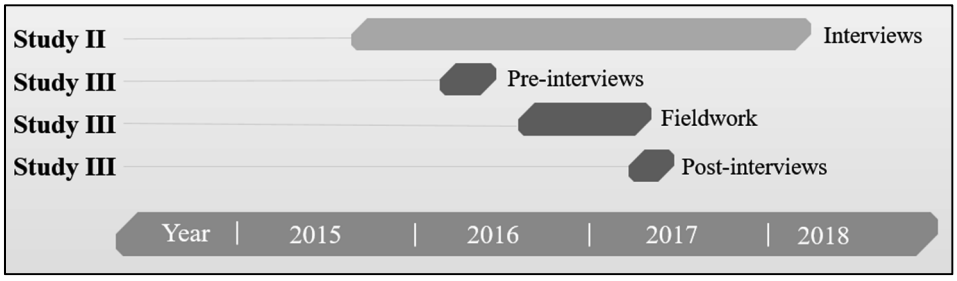

Figure 3. Timeline of the second and third study

The interviews in both studies were semi-structured. The interviews in the **second study** took place from October 2015 – March 2018. At first, 19 teachers were interviewed based on the questions in appendix A.1, then 10 teachers were interviewed based on the questions in appendix A.1 and A.2. After that the additional data was gathered from the same 19 teachers based on the questions in appendix A.2. After interviewing 19 teachers it appeared that the RRI concept should be treated more profoundly and therefore the questions of RRI dimensions were added and teachers were interviewed a second time. The pre-interviews in the **third study** took place from March 2016 – May 2016 (appendices B.1 and B.2) and post-interviews from March 2017 – May 2017. The observations in the field took place from September 2016 – May 2017.

The questions asked from the teachers comprised of the *responsibility*, *research, innovation*, *responsible research and innovation* and RRI dimensions in the **second study** (appendices A1 and A2). These questions provided the background data about the teachers' interpretation of the mentioned concepts as well as their understanding of the RRI dimensions in the school context. It is important to mention that the study concentrated on *responsibility*, *research*, *innovation* and *responsible research and innovation* in the context of RRI. The concepts similar to them (e.g. *relational responsibility* (McLeod, 2017) or *innovative education* (Marjanovic, 2013)) that had been addressed in previous educational literature outside the framework of RRI were not included.

In the pre-interviews of the **third study,** questions about IBL and RRI (appendices B.1 and B.2) and the post-interviews about responsibility in different phases of IBL and additional questions that emerged during the fieldwork were considered. The questions for the pre-interview (**third study**) were chosen at first to understand teachers' conceptions and interpretations of IBL and secondly to investigate how aware teachers were about the conception of RRI.

The length of the interviews varied from 18–132 minutes (average 59 minutes). The length of the interviews – from the author's point of view – did not influence the analysis and interpretations of the interviews as the ones that were shorter were at the same time informative and enriched the data. Almost all interviews were carried out by the author of the dissertation, only one pre-interview in the **third study** was carried out by another researcher and the post-interviews were carried out by the author of the dissertation or together with the other researcher. The pilot interviews for the **second study** were conducted by the author of the dissertation. The three teachers who were interviewed, also participated in the main study. In **third study**, the pilot interviews were included to the main study.

One part of **third study** were fieldwork observations. The framework of the observations entailed the concentration on the phases of IBL: their occurrence, interpretation and sequence. The aim of the fieldwork was to see teachers in action (Wolcott, 2005). During the fieldwork the researchers used the techniques relevant to ethnographic study such as observing teachers in their natural working environment as well as note-taking. The researchers also used the visual ethnographic techniques like taking pictures (Fetterman, 2009; Pink, 2001). The seven teachers were observed at least three times. In sum, the researchers observed 23 lessons and 19 different inquiries. There were 2–3 observers who were at present during the IBL lessons (there were in total five observers during the data collection process). During the class observations the researchers were fully engaged trying to record every moment. After each lesson the data gathered was discussed together and the conversation was audio-recorded for later analysis.

3.1.3 Data analysis

In both studies, the abductive content analysis was employed. The abductive analysis (Tavory & Timmermans, 2014) provides a good basis for the research, where the theory and the empirical data – here interviews and observation – are combined. The abductive analysis includes the elements that have not been earlier connected to the theory and thus enables a new interpretation of the phenomenon investigated. The analysis itself was conducted by "recursive movement back and forth between observations and theories" (p. 65). The analysis was suitable for both studies as the elements (e.g. RRI dimensions) were named earlier in the conceptual framework, but were not studied in education. Thus, the analysis needed a stronger interpretation, which, if using deductive or inductive approaches, would have remained one-sided.

In the abductive analysis, the theory and empirical facts are reinterpreted in the light of each other (Alvesson & Skoldberg, 2018). To begin with, in both studies the conceptual framework of RRI was taken into account before the abductive analysis process (Figure 4; 0).

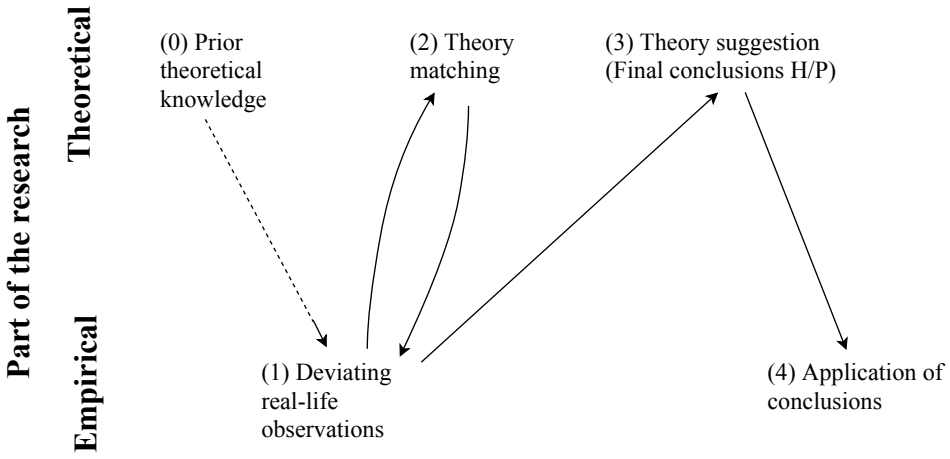

Figure 4. The abductive research process (Kovács & Spens, 2005)

The abductive reasoning began from the point where data gathered did not match with the prior conceptual framework (Dubois & Gadde, 2002; Kovács & Spens, 2005). The data was combined systematically in order to find the "matching" framework (Dubois & Gadde, 2002). This means that the empirical data (Figure 4, 1) was seen through the RRI dimensions in the **second study** or responsibility as care in the **third study** (0) which finally ended up with theory matching (2). All the process ended with theory suggestion (3) which in the **second study** meant the categories and subcategories (Figure 7) and in the **third study** the examples from the field.

Twenty interviews from the **second study** and all pre-interviews from the **third study** were transcribed fully in verbatim. All interviews of both studies were taken completely as the base of the analysis. Though, after the transcription and analysis of the 20 interviews in the **second study**, similar patterns emerged and thus the selective transcription was deemed reasonable (Gilbert & Stoneman, 2016). The selective transcription was also employed in the **third study**, because the transcriptions were not used to understand or generate the meanings of the data (Halcomb & Davidson, 2006), but rather as an additional data to support the findings from the fieldwork. The data was coded with another researcher independently and later, after the formation process, discussed together. The similar categories were identified and where the unclear conceptions emerged, the discussion was held until the consensus was reached. For the data analysis the Mindomo mindmap (https://www.mindomo.com), QCAmap (https://www.qcamap.org/) as well as Microsoft Word document were used. The mindmap helped to create the larger comprehensive characteristics whereas the QCAmap and Microsoft Word file helped to deal with data in a more detailed way.

During and after the data analysis process in both studies, the discussions were held between 2 – 4 researchers. The researchers reflected the data and took into account the theoretical insights during the discussions. In discussions, the

researchers additionally highlighted the schemas that came out from the data and compared and contrasted them with the existing conceptual framework of RRI. The discussions also helped create a logical structure and comparability of the categories. In addition, the data gathered was later presented to one informant to ascertain their comprehension and the informant's responses (Creswell & Miller, 2000)

In the analysis process of the **third study**, the researchers additionally took into account the pictures and recordings. The pictures that were the basis of the data analysis helped to recall the special moments in class and discuss the characteristics or topics that were beneficial in the data analysis process. The pictures enabled researchers to see the moments in detail and therefore to avoid any wrong interpretation. The researchers recorded the discussions or wrote memos after each discussion which allowed them to see the development of analysis and limit the researchers' perspectives (Levitt, Motulsky, Wertz, Morrow, & Ponterotto, 2017).

3.1.4 Trustworthiness of the study

In the current chapter the methodological integrity is considered that can be regarded as a methodological basis for trustworthiness in qualitative study (Levitt et al., 2017). The term "trustworthiness" refers to the validity and reliability in a qualitative study. The previous studies have stated that developing reliability and validity in qualitative research is challenging, especially because of the necessity to include subjectivity and creativity in the research process (Johnson, 1999). Winter (2000) has argued that the term validity stems from the positivist roots and is therefore not suitable for qualitative research. Hence, more appropriate terms have been developed to characterize validity, such as "trustworthiness", "credibility" or "rigor" (Creswell & Miller, 2000; Levitt et al., 2018; Thomas & Magilvy, 2011). The study as a whole, therefore, relies on the trustworthiness of the study in order to secure the validity and reliability of the study.

Trustworthiness refers to the value of the research and expresses the extent to which the claims are grounded (Levitt et al., 2017). The core of methodological integrity are fidelity and utility. Fidelity to the subject matter is the process where researchers choose various ways to develop and preserve dedication to the phenomenon under the study and which are realized within their approach to research (Levitt et al., 2018). Utility in achieving the research goals, on the contrary, refers to achieving the process where researchers choose the strategies that in an optimal way answer to their research questions and consider the aims.

3.1.4.1 Trustworthiness in data collection

In the current chapter the data collection is analyzed in the light of the methodological integrity (figure 5).

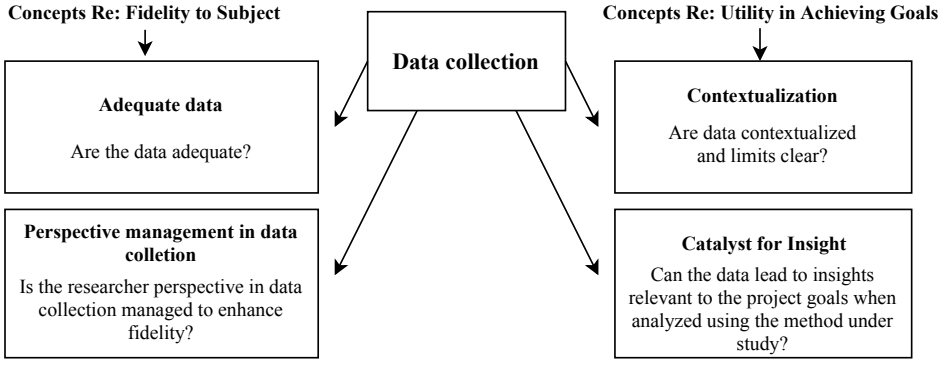

Figure 5. Considerations of methodological integrity in data collection (Levitt et al., 2017)

Adequate data. As for the higher fidelity, the data should be collected from different sources which are a basis for the variations of the phenomenon (Levitt et al., 2017). In the **second study** the maximum variation sampling was applied (Patton, 1990). Maximum variation aims to collect data from various people who participate in the study in different environments and in this way it is possible to determine the appropriate elements of the phenomenon under investigation (Patton, 1990). The variations that were considered in the **second study** were a) different types of schools (e.g. general education schools, extracurricular schools, Waldorf schools), b) teachers who taught learners of varying ages (learners aged 7–19), c) location of schools (urban and rural schools). In the **third study** the researchers tried to include teachers who taught learners of different ages (8–19 years old).

Perspective management in data collection. For the advantaged level of fidelity, the researchers should recognize the influence of their views on data collection and reduce the influence in order to get a more transparent picture of the phenomenon (Levitt et al., 2017). In order to increase the fidelity, the memoing technique was used. The memos were written in Mindomo mindmap or Microsoft Word file which gave the possibility of recordings for later critical review and to see the formation process of categories (**second study**; Birks, Chapman, & Francis, 2008). For the **third study**, the researchers wrote down the notes during and after the fieldwork and recorded the discussions between the researchers who participated in the fieldwork.

In order to increase the fidelity, the additional questions asked when interviewing the informants were primarily open-ended (nonleading) and the interviewer reflected the answers of informants during the interview process (Josselson, 2013). After the interview the interviewer asked if an informant has additional questions (Levitt, 2015). In the interviewing process, the data gathered depends on the situation or place where the interview is conducted and is influenced by the "dynamics of the *research relationship*" (Josselson, 2013, p.

x). In both studies, the informants could choose the place where they wanted to be interviewed.

Contextualization. In the subdivision of contextualisation, the overview of the researchers' background, the Estonian educational system and the teacher's previous contact with the IBL and RRI is provided. This is a basis to offer the context of the dissertation.

At first, a short description of the researchers is provided, the aim of which is to get acquainted with them as is suggested in a qualitative study (Levitt et al., 2018). Mirjam Burget, Emanuele Bardone and Margus Pedaste have developed the RRI concept and published the articles where RRI is concerned (Bardone et al., 2017; Bardone & Lind, 2016; Burget et al., 2017). They also have elaborated the concept of RRI in the EC project Ark of Inquiry. All the authors had a previous understanding of RRI as it was developed in academic literature. This helped to enhance the data collection and analysis and later, the empirical data was observed from this angle. The authors did not merely rely only on the EU vision of RRI, but rather tried to understand the multifaceted nature of the RRI concept and to interpret the actual meaning of RRI towards science education.

The other aspect to consider within the contextualization is the description of the background. The studies were conducted in Estonia and thus a short overview of the Estonian educational system is provided. The Estonian educational system comprises of pre-school education, basic education, upper secondary education, vocational education and higher education. Basic education in Estonia is compulsory and learners aged seven have to attend to school. After completing basic education, learners can continue their studies in vocational education or upper secondary education. In addition, there are the extracurricular schools where learners can participate voluntarily. For the current study, learners from basic education, upper secondary education, as well as extracurricular education participated.

One criterion for selecting the informants for both studies was that they practice actively IBL in their lessons. IBL exists in the Estonian national curriculum since 2002 (National curriculum for basic schools and upper secondary schools, 2002). The formal education teachers (basic and upper secondary school) followed the national curriculum, however, the extracurricular school teachers did not follow the national curriculum and the curriculum was principally designed by the teachers themselves. Before the study, the researchers made clear that extracurricular school teachers employ IBL in their work.

The teachers' preparation concerning the concept of RRI for both studies was different. For the **second study**, mostly those teachers were involved who did not have any previous experience with RRI, only a few of informants claimed that they had had a brief contact with the concept earlier. As for the **third study**, the researchers had to see how RRI is practiced and therefore the prior understanding of the concept was necessary. Thus, the training courses for science teachers were carried out from March 2015−March 2016. The content of the courses varied, addressing different topics, e.g. IBL and teachers' digital competences. Nevertheless, they contained an introduction to the concept of RRI as it was described

in EU political documents or projects funded by EU, e.g. Ark of Inquiry and RRI Tools.

Catalyst for insight. One possible way to improve the utility of the research is to gather the data that serve the rich grounds for the perceptive analyses (Levitt et al., 2017). The insightful analysis should be supported by staff with the specific awareness or training. As mentioned in the sub-chapter of contextualization, the three researchers of the **second and third study** had competencies in developing the concept of RRI. As for the interviewing skills, the interviewers had some previous experience in interviewing, but the skills in general were developed during the process.

3.1.4.2 Trustworthiness in data analysis

In this chapter the data analysis is presented in light of the methodological integrity (figure 6).

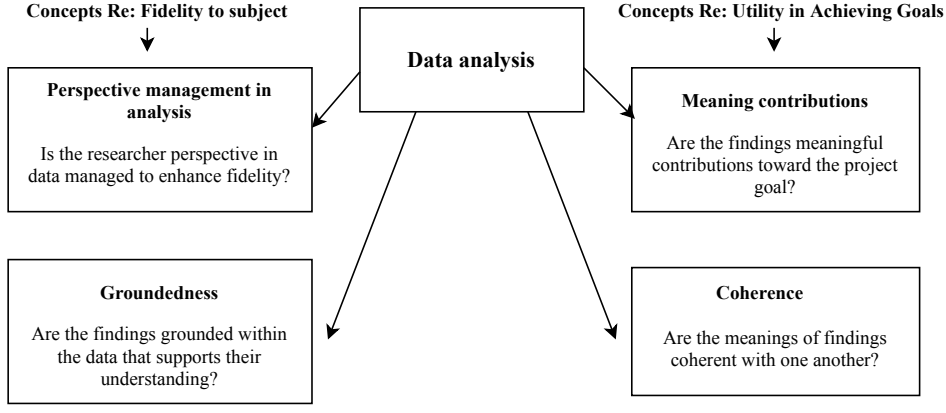

Figure 6. Considerations of methodological integrity in data analysis (Levitt et al., 2017)

Perspective management in data analysis. For the higher fidelity, the researchers should recognize how their perspectives affected or steered their analysis in order to achieve the transparent outcome in their analysis (Levitt et al., 2017). The data analysis of the **second study** is described in chapter 3.1.3. The aspects of the researchers' reflexivity as the basis of self-awareness is provided in chapter 3.1.5.

In order to apply the perspective management to the data analysis, dialogue with the informants was employed (Levitt et al., 2017). The participant checking should not be employed in order to validate or verify, but should be seen as development of the emerging findings and the source of additional data (Sparkes, 1998). The participant checking helped to understand how well the author's interpretations reflected the informants' understandings (Morrow, 2005). The details are described in chapter 3.1.3.

Groundedness. The fidelity is achieved when findings are underlying within the data that supports the comprehension (Levitt et al., 2017). Ensuring the

groundedness, the findings of the current dissertation are based on the data gathered and the data delivered was tried to present sufficiently to support the findings. Additionally, it was tried to address the relational/emotional experience as well as strengthen the contextual understanding concerning the material that was quoted (Levitt et al., 2017).

Meaning contributions. The possible way to increase the utility is to use the methods that allow the meaningful input in connection to the aims of the research (Levitt et al., 2017). The researchers used the abductive analysis which is described in more detail in paragraph 3.1.3.

Coherence among findings. The utility and the consistency is achieved by delving into variation within findings and demonstrating how they are connected to each other (Levitt et al., 2017). The researchers tried to make sense of the findings by, e.g. returning to the field for the additional data or using the RRI model in science education (Figure 11; Levitt et al., 2017).

3.1.5 Researcher's reflexivity

Sword (1999) has stated that there is no research free of the biases, assumptions and the nature of the researcher and it is not possible to be apart from the activities we are involved in. Therefore, in this regard, it is important to highlight the researcher's reflexivity in the current dissertation. Reflexivity is an understanding that a researcher and his or her actions and decisions may affect the meaning and context of the inquiry conducted (Horsburgh, 2003). To be reflexive means to pay attention to understanding self in creating the knowledge, one's own beliefs and personal experiences in research, and to identify the balance between the personal and universal (Berger, 2015). Subsequently, my role as a researcher, my relation to the informants, the advantages and disadvantages concerning my work-related history and professional competences are characterized in order to describe myself as a reflexive researcher.

I studied to become a biology teacher (MA) and continued my doctoral studies three years after my graduation. Before the doctoral studies I gained experience working in an extracurricular school where my work tasks included teaching the environmental media, carrying out educational programs for secondary and upper secondary level learners, heading the projects where the teaching materials for the secondary and upper secondary learners were created and mediating the environmental information for citizens. Working in an extracurricular school gave me an experience of developing and experiencing the extracurricular activities. Extracurricular school helped to see the world from the sustainable development prism, where the central aspect was to care about the nature. Later, during my doctoral studies, it was easier to involve informants in my research due to the earlier contacts in extracurricular school. In addition to the teaching experience in extracurricular school, I worked during my doctoral studies as a lecturer at the University of Tartu where the subject I taught was education for

sustainability (for primary school teachers, kindergarten teachers and vocational teachers).

Concerning my research skills, I have some previous experience in conducting interviews. I worked as an editor in a popular scientific journal with an environmental background. In this journal my task was to interview people from various backgrounds and to write articles. Before my PhD studies, I additionally had experience in writing a qualitative conference paper where I also conducted interviews with learners. However, I did not have the broad-based experience in conducting the research interviews before the PhD studies and the skills were mainly developed during the process.

In conducting the interviews, it is necessary to claim the process of interviewing. As I was Estonian, it was easier for me to conduct the interviews and the informants answered with ease. Also the earlier contacts were beneficial, and I could see that the informants opened themselves more easily when they were familiar with me. Though, it emerged that in interviewing the informants I had a previous contact with, they paid more attention to the previous common experiences. Therefore, interviewing those teachers I'd had no previous contact with, I obtained answers that were free of previous experiences or assumptions.

Another topic concerning the interviews was explaining the meaning of RRI and its dimensions. At first, a short explanation of the dimension was given to a teacher (see appendix A.2). After a while I waited for a teacher's interpretation of the dimension in a school context. In the cases where a teacher had trouble bringing forth the parallels to the school context I provided my own ideas (mostly based on the previous interviews) to help teachers to express their ideas on a topic. This, however, somewhat influenced the interview, but provided at the same time the smoothness of the process.

Another topic to address by interviewing was the power relations during the interview. Brinkmann & Kvale (2005) have recognized that the interviewer has a control over the setting, takes control of the script and asks questions in accordance with his or her interest in research. On the other side, the same authors admitted that the informants have a power – what they say and what are the outcomes of the interview. I recognized that the power was mainly shared between the interviewer and the informant. In order to keep the flow of the interviews on track, I employed some techniques. There were cases where an informant talked about the topics that were not topical. In this case I took the informant back to topic with subsequent questions, e.g. when the informant talked about innovation in general and did not connect it to school, then the next question addressed was about how the innovation in school can be considered. It also happened in some interviews that an informant started to ask questions from the interviewer (Anyan, 2013). In this case I did not want to give the ready-made answers and provided the additional open questions for the informants. Only in cases when the informants did not understand a topic under the consideration did I give examples.

I was principally the primary instrument of the data collection and analysis in the **second study** and therefore there could be bias from my side which could

affect the results of the study. During the analysis process I made the memos which helped to go back to data and see from which standpoint the data was analyzed. In both, the **second and third study,** I kept a diary, but keeping the diary was fragmented, most of the entries were made after the data analysis, and helped me develop as a junior researcher (appendix C). However, Nadin & Cassell (2006) have emphasized that keeping the diary during the qualitative research process is not considered necessary as a diary is usually kept in such contexts where there is less possibilities for discussions with fellow researchers.

Another issue which merits attention in the current study was describing myself as a responsible researcher. As the topic I studied was RRI, in different periods during my study, I had to position myself from the aspect of responsibility. The topic of my doctoral study was chosen by my supervisor, but also became increasingly familiar to me during the PhD studies. My doctoral studies began with reading the book "The Meaning of It All: Thoughts of a Citizen-Scientist" (Feynman, 2005). From this book I delivered a message which came along with me during my doctoral studies and which sounds as follows: "To every man is given the key to the gates of heaven. The same key opens the gates of hell. And so it is with science." (p. 5). This message posed several questions to me. For example, as regards wider social aspects, I realized during the study that researchers have a strong influence on society with their findings. With every step, as I analyzed the data, I had to ask: how could these results affect the citizens in future society? The last line of argument also resonates with the idea of the RRI, which provides that science has to be beneficial for the society as a whole. Therefore, to be a responsible researcher is an enormous challenge, being responsible for the whole society.

4. FINDINGS

The following sections provide the main findings of the research questions posed in the current dissertation. This paragraph concerns science teachers' perceptions of the emergence of RRI in school (second study), an understanding of the meaning of the term responsibility in IBL (third study); and finally reaches the complementarity of the RRI-related philosophies by describing the RRI model. The category "exploring" is described in more detail as this category comprises the findings both from the **second and third study**.

4.1 Science teachers' perceptions of the emergence of RRI in school

Based on the **second study**, the RRI dimensions in science education can be described as stated in figure 7.

Figure 7 shows that RRI in science education is described in four main categories: *sense-making*, *action-taking*, *exploring* and *inclusion* (a more detailed description is available in the fourth paper). The dimension *responsibility as care* goes through all the categories. The concept "sense-making" is described as an active process, constructing knowledge based on the previous values, knowledge, beliefs and experiences that are included within the social context in which people operate (Ganon-Shilon & Schechter, 2017). However, the concept "action-taking" is described as change-making in people's individual lives and encouraging learners to use the education of science and technology in order to help other people and the planet (Carter, Rodriguez, & Jones, 2014). Therefore, the mentioned names were considered appropriate to describe the categories of sense-making and action-taking. The dimension *sustainability* was not included in the dissertation, because the dimension would open up a whole field of research interest and would have therefore made the dissertation too wide-ranging.

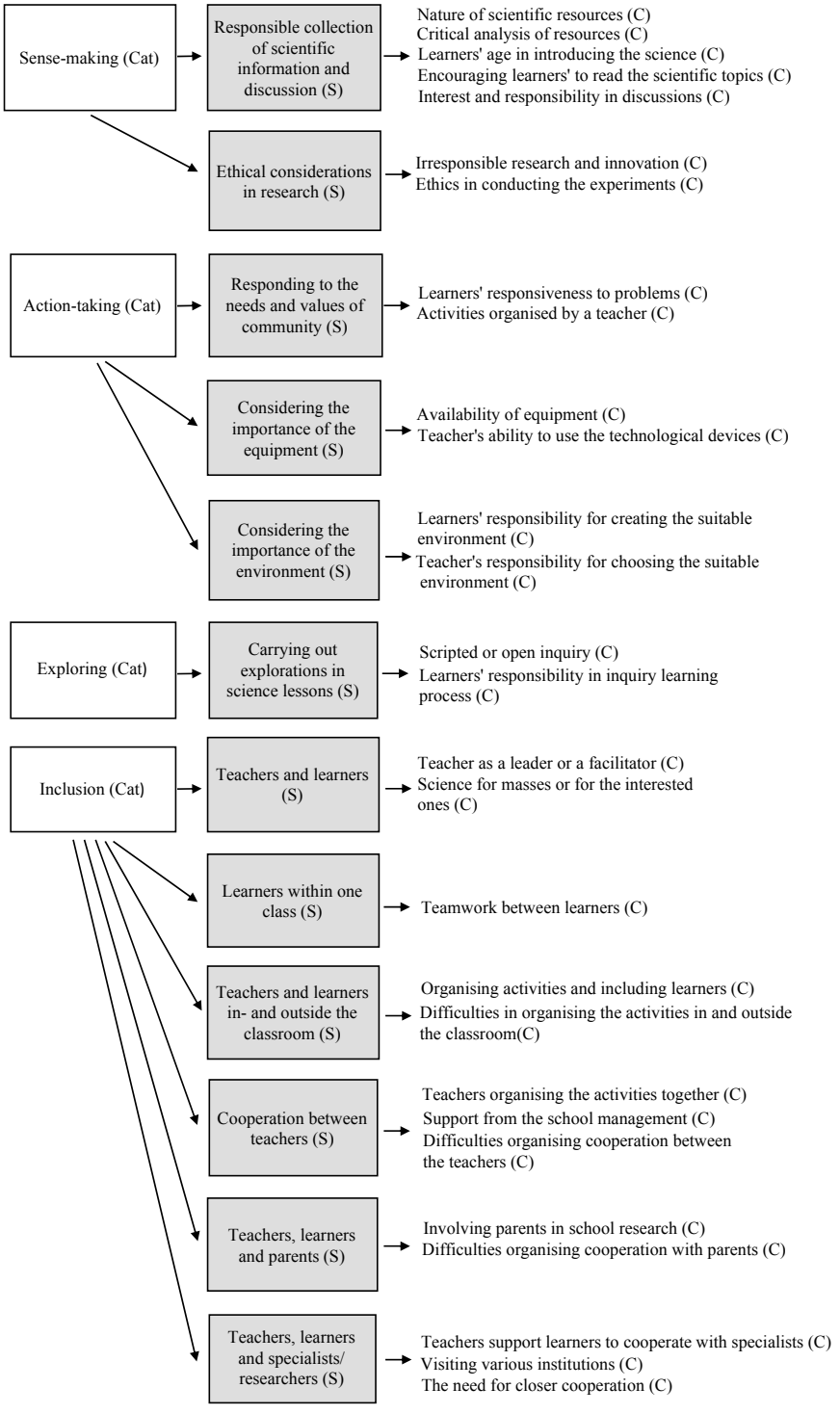

Figure 7. Overview of the categories (Cat), subcategories (S) and example codes (C) from the analyzed data (second study)

4.1.1 Sense-making

The category *sense-making* in science education is characterized as the responsible collection of scientific information, discussing the themes and issues in research (and innovation) and considering ethical issues as they arise. Informants mentioned that they normally get information from popular scientific resources for their lessons. However, teachers devoted their attention to where the learners can find trustworthy information and how learners should analyze the sources before using them. The knowledge teachers acquired from the popular scientific resources was used for stimulating learners' attention, introducing the topic, opening up the problem or to discuss various topics in more depth. In that regard, attention was paid to introducing the scientific topics in accordance with the learners' age. Learners were encouraged to get a good reading foundation in order to become more interested in the topic and – as a result – leading to an increase in the learners' sense of responsibility.

Ethical issues were treated in a cross-curricular way. The topic of irresponsibility in research appeared significantly. Here, for example, the discussions held with learners included the negative sides of science, the untrustworthy sources and teachers attempts to introduce learners' to reliable resources. In addition, the ethical use of digital devices and safe ways to carry out the experiments at school were discussed.

4.1.2 Action-taking

Action-taking in the current research means responding to the values and needs of the community with actions, and additionally taking into account the environment and technological equipment when carrying out the research activities. Responding to the needs and values of the community revealed a dichotomy in the teachers' answers: some teachers emphasized that learners should be responsible and take action, whereas other teachers stressed that the learners should not take the responsibility. The range of responsibility, however, also depended on the teachers' attitude towards responsibility and also the support of the school administration. Concerning teachers' responsibility in school-related issues, the events, e.g. conferences, project days or topic weeks were initiated and carried out; but also participating in citizen science projects was a way for increasing learners' responsibility.

The environment encompasses the room inside and outside the classroom. As for rooms inside, the school teachers valued the room design as a basis to take the responsibility. Concerning the room outside the school, the surrounding of school was deemed useful for learning, especially among teachers whose school was situated in countryside. As for the school environment, teachers valued the learners' initiative for the wellbeing and improvements of the surroundings.

The equipment means teachers' assessment of the availability of various tools for school research and the emphasis of support from the school management

about these issues. The IT tools were highly valued, but a concern about the teachers' own experience in using them was also emphasized.

4.1.3 Inclusion

Inclusion denotes involving different parties in the R&I process which means observing relationships between various parties. *Inclusion* in the **second study** is divided into six subcategories: (1) *teachers and learners*, (2) *learners within one class*, (3) *teachers and learners outside the classroom*, (4) *cooperation between teachers* (5) *teachers, learners and parents*, and (6) *teachers, learners and specialists/researchers*.

As for *teachers and learners*, the higher responsibility of involving different parties in the R&I activities lies mainly with the teacher. Teachers have to perceive their role as the leaders or facilitators. When teachers are more interested, they include learners in the R&I process more easily. A teacher is also the one who recognizes which learners are more interested and offers learners' the opportunities to go deeper into the matter.

Concerning *cooperation between learners inside one class*, the importance of involvement was emphasized as the science is similarly not undertaken alone. The group work is one example where the ability to take the responsibility emerged. Responsibility during the group work increases, because learners see how their work is linked to other learners' work.

In addition to the collaboration inside one class, the *cooperation between learners outside the class* emerged. The cooperation was proposed as a way to make learners more caring and to diversify the learning process. Here, for example, the project days, cooperation with other schools in foreign countries, and extracurricular school groups were mentioned.

The *cooperation between teachers* divided informants' answers in two: on the one hand teachers valued the cooperation of the teachers and school management; on the other hand, cooperation between teachers was challenging, mainly because of finding the common time and "language".

As in *cooperation between teachers*, the study revealed that *cooperation with parents* was valued, but mostly remained modest. The cooperation appeared in learners' awareness raising of parents' career choices and involvement of parents in school activities, including IBL.

The most necessary aspect for RRI, but also challenging at times for schools was the *cooperation between teachers, learners and specialists outside the school*. Cooperation with specialists outside the school was valued as specialists can make the topic meaningful and interesting for learners. Besides that, various institutions have provided the opportunities for learning outside the school, e.g. laboratories, science centres, museums or extracurricular schools. It was admitted that cooperation possibilities with various institutions should be facilitated and the will to create the community of RRI was highlighted.

4.1.4 Exploring

Both the **second and third study** concentrated on exploring. The category *exploring* entails conducting the explorations in IBL lessons, with regard to the teacher's way of perceiving the responsibility with learners in IBL lessons. An important aspect in this category was the way a teacher sees the IBL: a manner where the whole process is prescribed or a way that is more open and exploratory. As the **second study** was rather superficial in this aspect, the **third study** investigated in more detail the three categories proposed in the **second study**: *exploring* and *inclusion,* adding the *responsibility as care* that covers all the categories. *Inclusion* was described here as the way a teacher involves the learners in various phases of IBL as well as in the inquiry as a whole (inclusion as engagement). The aim of the **third study** was to gain a better understanding of the meaning the term responsibility can have in various phases of IBL. IBL was considered here as a way to discover and explore, and therefore an advanced way to create meaning for RRI in science education.

The next table (Table 1) represents in brief the results of the **third study** comprising the meaning that responsibility can have in different phases of IBL. In specific terms, it means how teachers involve learners in the inquiry process and which opportunities teachers give for learners to take the responsibility and manage it in a way so that they feel engaged. The inquiries we observed during the data collection process in a field were divided into two polarities: "the scripted approach" and the "unscripted approach" or "open" inquiry. The discussion phase was left out from the table as the phase emerged in all phases of the inquiry process and is, therefore, mentioned separately in the analysis of each phase.

The "scripted approach" means that the teacher gives learners' a step-by-step guidance, trying to reach to the one desired goal, and is therefore more results oriented. In this aspect the interviews revealed that teachers who tend to practice a more scripted type of inquiry want to follow the curriculum and they wholly steer the process that the learners should accomplish. For instance, one informant reported that:

> *In lessons I still allowed learners' to formulate [the research problem], but still it is clear what I want, for myself though. For them [learners] I do not say, rather they have to decide it by themselves, what is the problem /…/ They rather solve my problem, not their own.*

The "open approach" was described by giving learners' the maximum level of freedom to decide in different phases of inquiry and is therefore more process-oriented. In this case the teacher has a modest role and learners have a greater responsibility and thus feel increased ownership of their work. As one informant said:

Table 1. Variations of responsibility in the different inquiry phases (third study; Bardone et al., 2017)

Phase	Example 1	Example 2	Example 3
Orientation			
Background information on the topic	Delivered by the teachers directly	Delivered through a discussion initiated by the teacher	Searched for by the students divided into groups without direct teacher's assistance
Specific problem to address	Identified by the teachers beforehand	Identified by a discussion initiated by the teacher	Identifed by the students divided into groups without direct teacher's assistance
Conceptualisation			
Formulation of the research question or hypothesis	Provided by the teacher	Formulated through a discussion led by the teacher	Autonomously formulated by the students divided into groups
Investigation			
Design of the experiment	Provided by the teachers through the worksheet	Articulated in a discussion led by the teacher, in which students gave their own contribution	Articulated autonomously by the students divided into groups
Experimentation	Performed by the students while the teacher checked that everything was done correctly	Delivered through a discussion initiated by the teacher	Performed by the students divided into groups
Compilation of the results	Prompted by questions provided in the worksheet	Prompted by a discussion led by the teacher	Performed by the students in the class before the teacher
Conclusion			
How conclusions were reached	By writing down the results of the demonstration	Triggered by teacher's questions	None

The course of animal behaviour is where they [learners] fully set out … they do not have any plan. If anyone has an idea, that oh, let's bring a dog to school and let's do this [experiment] with this dog, so let's see what will come out of it.

The next paragraph gives a rationale for the IBL phases from the empirical data. It is important to note that in our study the inquiries that we observed followed the model by Pedaste et al. (2015). Therefore, the four phases were considered: Orientation, Conceptualisation, Investigation, and Conclusion. The discussion phase emerged in all phases of IBL and was concerned similarly in the current study. In every inquiry phase, the three examples are presented which characterize the variations of responsibility, located in the scripted, middle or open area.

4.1.4.1 The orientation phase

The scripted approach was described by the example of a biology class. Two teachers displayed a model of a human cardiovascular system on the screen to introduce the topic for learners. They took the responsibility to provide the background information for learners about their inquiry. After the introduction part learners downloaded the template from the repository which contained the prescribed inquiry phases that the learners had to go through.

The example between the scripted and open approach belongs to the teacher who introduced the topic of measuring the temperature of peoples' bodies and various spots inside and outside the school. The teacher decided what to inquire and took the responsibility to introduce the topic for the learners. The background information was provided for learners through the discussion which gave them the opportunity to express their own opinion. In addition, learners also brought along their own thermometers. It was revealed in the post-fieldwork interview that the teacher often asked learners to bring in their own equipment as she feels that in this way learners are more included. The other aspects of this inquiry did not include the ways where the learners were free in their decisions, therefore this concrete example is located in the middle of the scripted and open approach.

The example of the open inquiry belongs to the elective course that the gymnasium students could choose voluntarily. The IBL lesson was spread across the 45 minute lessons on three different days. The general theme of the inquiry was selected by the teacher and the teacher gave a short introduction for the learners' about body language and optical illusion in order to encourage the learners' creativity. Learners could independently decide which topic to choose and problem to address. Further activities were carried out by learners in groups which they had formed themselves. Learners had to design and carry out the experiment on the second day and present the results on the third day. Learners were also allowed to work outside the class and choose the time frame.

4.1.4.2 The conceptualisation phase

In the previous paragraph the inquiry of a cardiovascular system was described. This concrete inquiry was similar in the conceptualisation phase to the more scripted nature. After the short clip showing the main parts of the heart, the learners had to estimate their heart rate while resting and then after running. Learners had to write down their hypothesis. In this concrete case the learners were not given the opportunity to conceptualize the topic studied. The post-fieldwork interview confirmed the fact as a teacher claimed that learners should give the answer that a teacher expects while the learners own research questions would render the class unmanageable.

Concerning the example which was positioned between the scripted and open approaches, an example here could be the inquiry which was about reflex arc and reaction time. At the beginning of the lesson the teacher introduced the topic and then involved learners in formulating the research questions. The teacher explained for the learners that the reaction time can be faster or slower and asked the learners to think about the research question based on their previous knowledge. With the teacher's assistance the whole class finally came up with the research question about how various factors influence reaction time. What distinguishes this case from the previous one was that the teacher involved learners in the research question formulation process and was at the same time open to learners' comments and ideas during the research question formulation process. In the post-fieldwork interview the teacher said that their role in the class is to "monitor and guide the process".

The third case about the open type of inquiry was the same that was presented in the orientation phase. When the teacher finished introducing the topics connected to body language and optical illusion, the learners were left alone and could decide which topic they wanted to investigate. In the second lesson, all learners introduced their research questions or hypotheses.

4.1.4.3 The investigation phase

The investigation phase consists of three sub-phases, namely, designing the experiment, experimentation, and the compilation and passing the results to the teacher and other learners. As an example of the scripted version of the investigation is the inquiry lesson where calculating the volume of a cylinder was the goal (Figure 8).

Figure 8. An example of the scripted type of inquiry: A teacher helps the learners follow the instructions provided in the worksheet (third study)

The experiment was done in a way that a cylinder was put in a small bowl which contained water. Learners had to measure how much the water level rose. Before the experimentation, a teacher went step-by-step through all the instructions provided in the worksheets, and showed one-by-one the tools that learners were to use to accomplish their experiment. The teacher also showed the learners how to measure the diameter of the cylinder and paid careful attention that learners use the right units. When learners started with the experimentation they decided inside the group how to implement the plan that the teacher had prepared. Learners tried to exactly follow the teacher's instructions in order to avoid failure. After finishing the experiment, the learners had to fill in the worksheets the teacher had prepared. There was no discussion after they had completed their worksheets.

Figure 9. An example of an inquiry between the scripted and open approach: Teacher and learners are trying to capture a moment about the place of the buried items (third study)

The second case which moves closer to the open approach concerns a lesson where learners had to bury various materials in the ground in September and to dig them up in May to see how they had degraded in the soil (Figure 9). The teacher gave the learners' various possibilities to make decisions before they started their inquiry. For example, the learners had to bring along the items they had to bury. Learners could also discuss and finally decide, with the teacher's assistance, where to dig the hole and later how to find the hole.

The last example is closer to the open type of inquiry. Here, the same inquiry in the elective course is used as an example (Figure 10). So the group decided which topic to choose with the teacher's introduction of optical illusions and body language. Surprisingly, they chose very different topics under the teacher's introductory umbrella topic. Learners also had to decide how to collect data in their study. During the study, learners included the teacher in the process, e.g. filming the experiment or participating in the experiment. The teacher asked the questions during the inquiry to trigger the learners' curiosity, rather than assessing them. As for the results part, learners' groups prepared the slides where they showed their research question, design of the experiment or results. When learners presented their results a teacher stood at the back of the room and commented on the presenters' work by acting as a supportive reviewer.

Figure 10. An example of the open type of the inquiry: A teacher is participating in the inquiry process created by the learners by answering on his mobile device learners' questions in the data collection process (third study)

4.1.4.4 The conclusion phase

Similar to earlier results, the first example is the scripted type of inquiry. The example was about a chemistry lesson where learners had to design the experiment about CO_2 formation in a chemical reaction. Learners had to demonstrate in groups the experiment which was previously designed at home. All groups decided to burn a match to show the formation of CO_2. The experiment was rather demonstrative, learners were asked to write down the results of the demonstration and were not obliged to analyse the experimentation process. In the conclusion phase a teacher asked each group how they knew that CO_2 was formed. In those cases where learners did not get the result that they expected a teacher explained that something in the experimentation went wrong. In the conclusion phase the teacher asked from the learners to explain the reason for CO_2 formation and to look up the answer from their handbooks.

The second example of the conclusion phase is from the same teacher who buried, with the learners, items in the ground to see their decay. The conclusion phase took place in May when the items were dug up. After the excavation the teacher led the discussion where the learners participated actively. The teacher responded to each learner's answer with care and did not wait for the one right answer. The inquiry lesson ended up with the final reflection where the learners had to express what they enjoyed the most during the inquiry learning process.

The teacher stressed during the discussion process that there is no one right answer and all learners can share their opinion.

As for the more open type of inquiry, no particular example was identified. Nevertheless, it would be interesting to see how the conclusion process of the upper secondary school learners, who chose their course voluntarily, ended up. The investigation phase was completed with each group presenting their results of inquiries. The teacher's role here was as a reviewer who provided feedback, principally on the design of the experiment. The teacher in providing the feedback went through the phases of the scientific inquiry. They paid special attention to describing all the inquiry phases, because in this way learners could understand what they did and why they did it. The teacher also added that what they did differently in the learners' presentations, stressed the significance of the sample, and which results should be presented visually. The learners listened with interest and took photos of the schema that the teacher presented. There was no discussion afterwards.

4.2 The RRI model as a way to make sense of RRI in science education

The main result of the current dissertation was the RRI model in science education (Figure 11) which was based on the science teachers' perception about how to make sense of RRI in science education (second and third study). In more specific terms, the RRI model was derived primarily based on conceptualising the RRI (first study) which was revised according to the empirical studies of the current research (second and third study). RRI in science education can be explained by the model, where teachers include learners meaningfully in a process where learners are given an opportunity to make sense, take action, or explore the scientific knowledge or the technology-related processes.

The RRI model consists of three different temporal coordinates: past, present and future. The past means *looking backwards* or to see what we have done, the present means what occurs in our surroundings and comprises the response to it and the future means *looking forward* to explore. The categories that emerged in the **second study** (*sense-making, action-taking and exploring*) are named as branches in the RRI model. In the next paragraphs the temporal coordinates together with the branches are described (see more in detail from the fourth article).

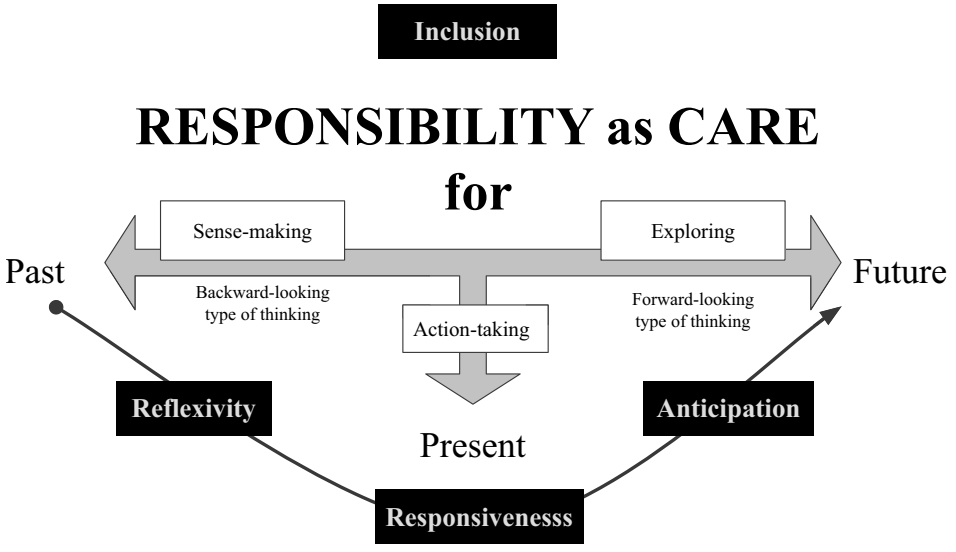

Figure 11. The RRI model in science education

4.2.1 Backward-looking: responsibility in sense-making

The backward-looking type of branch means making sense of what has happened: this, however, may entail the process which is still continuing or has already finished. In literature, this process is called "reflexivity". Sense-making is like a bird's eye view on the projects that have been carried out, the strategies that have been implemented, or the decisions made during the process. The general idea is to look backwards at things carried out in order to get a better understanding. The reflection in this process can be, e.g. first-order reflection which means the reflection how the particular activities have been carried out, but can also be the second order reflection which means providing a wider meaning of what has been done. The discussion may entail, e.g. discussions about science or the way innovation is seen in today's society.

4.2.2 Present-looking: responsibility for responding immediately to recurring issues

The present-looking branch devotes attention to what is happening now and is concerned with taking action concerning the concrete issues. In research literature, the process is called "responsiveness" (Burget et al., 2017; Stilgoe et al., 2013). Taking the responsibility now means responding to the immediate concerns. The example of this branch include, e.g. the problem of youngsters playing games on smartphones and the immediate actions – such as banning the mobile phones, or only allowing use during an allocated time in school.

4.2.3 Forward-looking: responsibility for exploring the opportunities

The forward-looking branch means exploring the possibilities about unknown things, laying the groundwork for openness and uncertainty. This branch also emphasizes creativity and imagination. Although in research literature this branch is comparable with the conceptual dimension anticipation (Stilgoe et al., 2013), the anticipation and the branch of *exploration* in science education cannot be understood in the same way. In the educational field, more room is left for exploration, because learners are unable to comprehend the long-term effects of scientific achievements. The activities that characterize this branch include, e.g. the exploration in an IBL lesson where learners can explore a phenomena unknown to them.

4.2.4 RRI in existing philosophies in science education based on the RRI model

To provide the comprehensive picture of RRI in education, the philosophies in science education are analysed through the RRI model (Figure 11). The general idea is to provide the main implications of practicing RRI. The RRI model therefore helps to include philosophies in science education which were considered separately earlier (see more in detail from the fourth article).

4.2.4.1 Inquiry-based Learning

The IBL conveys the basic idea of the branch of exploration. In this philosophy a higher level of engagement is expected from learners and they are expected to pose the questions or phrase the hypothesis, explore the phenomena, and find out the solution to the stated problem (Pedaste et al., 2015). Therefore, it means a higher responsibility is given to the learners. Although IBL should construct the knowledge and reach meaningful understanding of the phenomena under the investigation, the sense-making is still not the prevailing branch in IBL (Minner, Levy, & Century, 2010). Similarly, although the action-taking appears in IBL; it is not reasonable to consider it as the dominant branch.

4.2.4.2 Nature of Science

NOS is predominantly situated on the branch of "sense-making". The reason is that NOS concentrates on the epistemological questions in science, the beliefs and values as well as historical developments which characterize the science (Abd-El-Khalick et al., 1998; Erduran & Dagher, 2014). The content of NOS deliberates how the science actually "works". It is important to underline that the teacher is guiding the process of making sense of NOS, therefore it is the teacher's role to have a wide-ranging understanding of the philosophy and to give terminology and examples of the philosophy, but also to carry out the critical

discussions with students in order to create a basis for the meaningful understanding of the concept (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). The other branches – action-taking and exploration – are modestly represented in the NOS philosophy, as the philosophy does not require immediate action or exploration.

4.2.4.3 Socio-scientific Issues

The nature of SSI means mainly covering the aspect of sense-making. The sense-making branch appears by analyzing and synthesizing the information, evaluating the information critically and taking into account different perspectives (Zeidler, Sadler, Simmons, & Howes, 2005). As SSI is a complex philosophy for teachers (Simonneaux & Simonneaux, 2009), the advantage of connecting SSI to RRI is that RRI adds another dimension – making sense of multifaceted problems in society. Therefore, the SSI characterizes the sense-making and creates a basis for understanding and meaningful learning. The other branches – action-taking and exploring – do not appear significantly in SSI philosophy, although SSI may entail elements of both branches.

4.2.4.4 Citizenship Education

CE has two leading branches: sense-making and action-taking. As for the sense-making, learners are enabled to make sense of the processes and systems in society so that they can actively participate in today's world. The argumentations skills, problem solving or debates support the process of sense-making and are responsive to problems (Gifford & Gomez, 2014). The action-taking branch means that citizens' are expected to be active in society (Geboers et al., 2013). However, exploration is the branch that does not characterize the CE as CE does not mean to learn by discovering.

4.2.4.5. Socio-scientific Inquiry-based Learning

SSIBL is considered as a hybrid approach and covers all the branches described in previous chapters. Therefore, the SSIBL is not, in turn, explained based on the RRI model in education (for further information read the fourth article).

5. DISCUSSION

In the current chapter the findings will be discussed in accordance with the **second, third and fourth studies**.

Sense-making as a way of describing RRI in science education. One possible way how RRI can be described in science education is the *sense-making*, which means gathering information responsibly, reflecting and discussing the problems or questions in research (and innovation) and considering the ethical questions when they arise in school. In this context, it is important to note that sense-making is derived from the dimension *reflexivity*. The dimension had to be changed as it was expressed in a different way in the school context to how it was stated in the research literature. Reflexivity in research refers to the cause-effect relationship and is characterised as a process which aims to shape the innovations (Setiawan & Singh, 2015), the role of the participants here is to reflect on probable futures, needs, values, perspectives, interests and choices, and share the responsibilities in the R&I process (Stilgoe et al., 2013). It is evident that considering RRI in this way is inappropriate in the school context. In addition, science teachers highlighted in their interviews that science is not easy to understand for learners, especially the younger ones in grades 1−6 (7−12 years old). Their daily activities concerning science start with small inquiries as a way to maintain the interest of the children. Thus, in the **second study** the dimension was shaped in a way that it would be suitable to the school environment, covering how to maintain, with the information, and to pay attention to, the ethical issues.

The conversations about the ethical issues was one distinct topic that emerged in interviews. The interesting finding was that talking about responsible research and innovation, teachers first stressed examples from the unethical side. The probable explanation for this could be that it is easier to talk about what is irresponsible research and innovation rather than what is responsible research and innovation. Besides that, the unethical issues raised by the learners did not remain unnoticed by the teachers. The ethical questions arose in accordance with the situation and the teachers were ready to address them. The emergence of ethical issues in this manner shows clearly the emergence of the dimension *care* in the school environment (Tassone et al., 2018).

***Action-taking as a way of describing RRI in science education*.** The second way in which RRI in science education emerged was *action-taking* which denotes from one side how the responsibility is perceived or negotiated between learners and teacher, but on the other side how teachers perceive their responsibility for choosing the suitable tools, environment or activities for learning. As with the previous category, *sense-making*, the dimension of *responsiveness* had to be adapted to the circumstances within the school. In research literature, *responsiveness* is described as being responsive to the problems or opportunities when they arise (Bardone & Lind, 2016). The dimension comprises a broader perspective covering the wider involvement of the society in the R&I process. It is clear that young children may not be ready to take responsibility for solving public

problems, but they are capable of taking responsibility in a way that is manageable for them. Here the teacher's skills and attitudes play an important role: how teachers perceive their opportunity to negotiate responsibility in order that a responsible member of the future society can develop.

The teachers' responsibility concerning the category of *action-taking* was clearly identified. Teachers saw their role in various aspect, e.g. the environment which could be chosen for activities or tools which helped to undertake the activities, and also recognizing the opportunities in society in order to actively take part in research activities. A prior study of Sperling, Wilkinson and Bencze (2014) supports the idea of providing the learners' with the physical and intellectual sources for their studies, so the orientation towards citizenship will improve. Additionally, teachers in interviews stressed that the possibilities to take part in science popularisation events has improved recently and there are better possibilities for increased participation from teachers and learners. Thus, the changes in society have a respectable ground for inclusion and taking action.

Inclusion as a way of describing RRI in science education. *Inclusion* can be considered as a core dimension of RRI, as inclusion appeared is a part of all the categories of RRI: *sense-making*, *action-taking* and *exploring*. The dimension *inclusion* in research literature is characterised as involving different parties with the R&I process at an early stage to achieve the results that society expects (Asante et al., 2014; Owen et al., 2012). The **second study** did not concentrate on ending up with socially expected outcomes, but data collected by interviews illustrated the actual relationships between different parties connected to the schools. In a school context we can talk about communication and collaboration abilities which are listed as 21th century skills (Trilling & Fadel, 2009). Therefore, paying attention to the inclusion gives an opportunity to develop those skills among learners.

The primary responsibility to include various parties lies mainly with the teacher. Teachers respond to learners' involvement and find the methods or ways to increase involvement, but also to find different ways to include various parties in the R&I process. Thus, teachers can be regarded as core players concerning inclusion. When teachers feel they are involved, it may also lead to the learners' involvement too. The previous studies have shown the importance of emphasizing inclusion in educational settings (Heras & Ruiz-Mallén, 2017; Majorek & du Vall, 2018), but RRI-related studies have been unable to show clearly how the actual relationships in school are formed, or teacher's role in forming those relationships. Therefore, the **second study** provided a comprehensive overview of this topic.

Exploring as a way of describing RRI in science education. The **third study** encompasses the three formerly mentioned RRI categories: *exploration* and *inclusion* and *responsibility as care* which goes through all the mentioned categories. Anticipation in academic literature is explained as having a future-oriented view, taking into account the opportunities or risks in the R&I process (Owen et al., 2012; Te Kulve & Rip, 2011). *Inclusion* is observed as the way the teacher involves the learners in various phases of inquiry as well as to the inquiry

entirely. The latter is comparable with the degree of engagement during the lesson. The dimension *anticipation* was translated – similarly as in the previous cases − to the educational "language". Here, more attention was paid on exploring, as especially younger children are not able to analyze the forward-looking issues in society (Biesta, 2015), but are more exploratory instead. In the present study, the exploring means using the IBL method, because exploring is the key element in IBL. The IBL concept itself refers to taking personal responsibility: to explore what is unknown (Pedaste et al., 2015). The **third study** revealed that *responsibility as care* in IBL appeared in continuum whose ends are situated in two polarities: the scripted type of inquiry and the open type of inquiry. The following paragraphs are dedicated to a discussion on these.

The way teachers practice IBL depends on their interpretation of IBL. It should be noted that a teacher's vision of *responsibility as care* as a dynamic process plays an important role here. The term "responsibility" can be addressed from one part as "accountability" or "liability" (Lucas, 1995). Liability has been interpreted as having a responsibility towards somebody or in other words to be accountable, that is related to somebody's control, management or power (Cook-Sather, 2010). In the educational field, accountability is seen as learners doing what adults tell them to do (Cook-Sather, 2010). Teachers and learners are seen as working in distinct areas, and learners are seen from a "follow-my-leader" perspective.

Responsibility as accountability can also be seen as a triadic relationship where points assign (1) a person who is responsible for (2) a third party about (3) committing a special task (Lucas, 1995). That means: a person has to accomplish a task given by a third party and the third party here delegates to the person. The same triadic relationship appeared from the results of describing the meaning that the term responsibility has in different phases of IBL in the **third study**. This relationship is close to the "scripted" type of the inquiry and here learners were responsible for the process of inquiry to accomplish something in the way a teacher envisaged it. At the same time, teachers provided learners with support in a way that they fully led the process, and the learners were performing the command. In the orientation phase, for example, this meant that the teachers took a greater role by introducing the topic, setting the problem and providing the prescribed worksheet for the learners. The similar result emerged in the conceptualization phase where the learners had to give answers to the question that was already conceptualized by the teacher. Interestingly, in the investigation phase – even in the most scripted examples – learners had the opportunity to be active. Though the teacher did not remain in the background, but rather controlled the process and pushed learners to accomplish their task. This, however, may also result from the limited time of the lesson. Continuing with the conclusion phase, teachers affirmed that learners achieved the results they expected, but the interesting or unexpected results remained unnoticed.

It can be regarded as normal that following the rules may be one part of education, but practicing excessive accountability may lead to the development of the learners as obedient followers. Moreover, the prescribed rules do not offer

an opportunity to understand, e.g. the nature of science where the complexity of the research process and learning from trial and error prevails. Thus, learners could miss out on the opportunity to "do RRI", and to be wholly committed to the research process. The previous research shows that prescribed rules do not allow the development of a learners' processing skills and abilities to make judgements (Wang & Lin, 2008), and also structured inquiry does not allow the development of scientific and critical thinking and the attitudes that go along with it (Kaberman & Dori, 2009).

If we now turn to the other side of responsibility which is described with the word "care", we see a different phenomenon. *Responsibility as care* is characterized by the open type of inquiry where learners are more included in the process of R&I and this can be described as "doing RRI". When learners feel they are more included, the process itself becomes more meaningful for them; however this process also helps learners to be more active (Cook-Sather, 2010). So the learners take ownership, which allows them to clearly understand the process and their agency, helping to acquire the scientific knowledge (Anastopoulou et al., 2012). It should be noted here that inquiry itself should not be seen in a dichotomous way – the scripted or open −, but rather as a way to dynamically expand or shrink the space. This means that in some aspects the higher responsibility is on the teacher whereas in other cases on the learners.

The open type of inquiry in the orientation phase emerged so the teacher let the learners choose the topic by giving ideas to nurture the learners' creative process. Learners formulated the research problem and the research question on their own and also the investigation was designed and carried out by the learners themselves. The teacher's role was to facilitate the process by giving hints or providing assistance when needed. As for the conclusion, the open type of inquiry was not apparent in the **third study**. A possible explanation for this might be that although the teacher prepared the open inquiry lesson purposefully, their actual aim was to conclude the inquiry by showing learners' where they could end up. Probably without the teacher's strong input, the effectiveness of the learning would have remained modest. This also shows the teacher's ability to shrink or the expand the continuum of the open and scripted type of inquiry.

In this concrete example of open inquiry, it could be seen that learners were entirely involved in the inquiry they were completing. The process itself became meaningful for them, which can be characterized in other words as "doing RRI". Thus, "doing RRI" means the meaningful engagement with and in the inquiry which allows learners to take the ownership and experience what it means to take the responsibility for one's own learning. It must be noted that open inquiry itself is a challenge for the teacher (Kazempour, 2009), and learners and teachers need to be flexible (Kirch, 2010). The example of the open inquiry demonstrated that in certain conditions it is possible to carry out the investigation in an open way: the flexible frames of a non-optional lesson allowed it. It's likely that practicing a more open type of inquiry also depends on the teacher's experience and encouragement, giving learners' the opportunity to take more responsibility. This,

however, in practice may lead to the teacher's more profound and meaningful understanding of inquiry and responsibility itself.

RRI in existing philosophies in science education. The RRI model (Figure 11) helps to open the existing philosophies in a more coherent way, to show their complementarity, and is the source of portraying RRI in science education. Subsequently, the philosophies are discussed along with the RRI model.

The branch to choose in the educational setting is closely connected to the goal. For instance, if the goal is to *make sense* of the scientific knowledge, the philosophy NOS can be considered appropriate. The discussions held can be the second-order reflections with the aim of reaching an understanding about the NOS (Abd-El-Khalick et al., 1998). The learners in this process are engaged meaningfully to make sense of what science means.

Sense-making does not only mean the achievement of a profound understanding about the nature of science. The second-order reflection may bring forth controversial issues which partly can be originated from the science. In this respect, SSI can be the most suitable candidate. SSI learners can be open to debate and discussion, and contrary to NOS do not need to have a previous thorough knowledge of the science as such. However, CE is a suitable candidate when both the sense-making and action-taking branches should be present, because CE at the same time needs active participation as well as making sense of how the society is constructed (Schulz et al., 2016).

The last branch is *exploration* which allows learners to be involved in first-order explorations. In the process of exploration, learners' are given an opportunity to take ownership of the process (Pedaste et al., 2015). The first-order reflections are included in all phases of IBL (Pedaste et al., 2015) whereas the second-order reflections in science remain modest. However, the sense-making and action-taking do not play an important role in exploration.

In relation to the aforesaid it can be concluded that the philosophies should not be seen separately, and they also can be seen as the opportunity for the transition from one philosophy to another. For instance, the learning process can start with exploration (IBL philosophy), making sense of the phenomena through discussions (SSI philosophy) and finish with taking action (CE philosophy). At the same time, it should be noted that the aim of the model should not be to generate the complex philosophies, but rather provide a starting point to create an ability to move professionally from one branch to another depending on the educational aim. This, however, requires teachers to have an understandings of the philosophies, to use them meaningfully, as well as the skills to move skillfully from one branch to another.

6. CONCLUSIONS AND RECOMMENDATIONS

The following paragraph provides conclusions which also comprise of practical implications, limitations of the studies, and suggestions for further research.

6.1 Conclusions

This dissertation aimed to contribute to the growing area of research by exploring the nature of RRI by explaining the definitions and dimensions of RRI, the way science teachers perceive RRI in school, as well as providing an in-depth exploration of the term responsibility in different phases of IBL. As a result, the model which describes RRI in science education was provided.

The studies I–IV gave an answer to the four research questions as follows:

- The **first study** showed that RRI can be described by academic and administrative definitions. The academic definitions are characterized as the definitions which are derived from the policy makers and funding agencies of the EU, the academic definitions, on the other hand, are developed by the academics. The study showed that the administrative definitions were broadly quoted, but not considerably developed further. The academic definitions were generally developed from the administrative definitions. Based on the definitions, RRI is described as a process to govern R&I by purposefully including at early stages all relevant parties in anticipating and discerning how R&I can be beneficial for the society. Overall, these results indicated that empirical studies are needed so that a wide-ranging basis on the elaboration of the concept of RRI is available. Secondly, the study defined four conceptual dimensions of RRI: *reflexivity, responsiveness, inclusion,* and *anticipation*. To the aforesaid dimensions, two emerging conceptual dimensions were included: *sustainability* and *care*.
- The **second study** has demonstrated that science teachers perceive RRI as (1) *sense-making* – which entails gathering the information responsibly, discussing and reflecting on the issues and challenges in research (and innovation) and having regard to the ethical considerations as they arise in school; (2) *action-taking* – taking action towards the problems or issues in a community and taking into account the value of the environment and (technological) tools; (3) *exploring* – conducting the explorations in IBL classes and considering how the responsibility is negotiated between the teacher and learners in IBL lessons; and (4) *inclusion* – including various participants in the R&I practice in school.
- The **third study** has demonstrated, for the first time, how to make sense of RRI in science education by concentrating on the meaning of responsibility in IBL lessons. The term "responsibility" could be associated with the meaning of "accountability" which in practice occurs as following the prescribed rules

set by a teacher. On the contrary, when a teacher is concentrated on inquiry learning as a more open type of inquiry, the way of collaboration can be mentioned as "meaningful engagement". Thus, it can be claimed that "doing RRI" in science education is understood as meaningful engagement with and for the inquiry which enables the learners to progressively take ownership and to experience what it means to be responsible in the inquiry process – a process that is open and not pre-determined.

- The **fourth study** was designed to determine the complementarity nature of various philosophies in science education and to consider responsibility as part of the philosophies. The study has shown that RRI in science education can be explained by the model where teachers include learners meaningfully in a process, where learners are given an opportunity to *make sense*, *take action* or *explore* the scientific knowledge or the technology-related processes. RRI can be considered as an umbrella-conception which brings together various philosophies and makes sense of these philosophies from the perspective of *responsibility as care*.

6.2 Practical implications

Based on the empirical findings, different recommendations are apparent for teachers, curriculum and learning material developers, and policy makers.

Teachers:

- The model itself has to be explicit for the teachers so that they understand the nature of the philosophies and *responsibility as care* which runs across all the philosophies. The model also demands the skilful transfer from one branch to another depending on the educational goal. However, the model should be implicit for the learners throughout the learning process because of its complex nature.
- Practicing RRI in science education is complex to some extent. The effective application of RRI in science education at first requires the teacher to analyse their everyday practice in the light of the RRI model in education. This may also mean analysing the ability to negotiate the responsibility between the teacher and learners. It may appear that for some teachers it means accepting a specific level of openness and uncertainty which may be in conflict with what teachers think they are supposed to do.
- One of the issues that emerged from the findings was a need to form a community in support of teachers practicing RRI in science education. These findings refer to the need to find new ways of including a variety of people in the RRI development process. The community should also include researchers who can explain, e.g. the nature of science and its role in society for the teachers as well as learners and other parties concerned.

- The results have important implications in applying the RRI model to other levels of education if modified, e.g. higher or early childhood education. Thus, these findings create a basis for further development of the RRI model in a wider context for education.

Curriculum and learning material developers and trainees:

- The RRI model has important implications for developing the national curriculum of Estonia. The Estonian national curriculum entails the notion of responsibility, but the meaning of responsibility is not sufficiently open. Thus, the national curriculum needs an explanation for the term responsibility. Moreover, the curriculum explains the nature of philosophies in science education, but to a very limited extent. Therefore, the profound explanations of various philosophies in the curriculum would open their meaning and minimise ambiguities.
- As the concept of RRI is new in science education, there is a shortage of learning and teaching activities, as well as teaching materials which concern RRI. Thus, there is a need to develop materials which would make it easier to adopt RRI in science education.
- The concept of RRI in science education can be introduced by in-service courses for universities. The courses allow teachers to analyse their current practice and see which parts of RRI are not opened and require more attention.

Policy makers:

- The studies conducted have important implications for developing the RRI concept itself while practiced in science education. First of all, these findings show that RRI should not be considered solely as a political measure, but as an evidence-based conception. Thus, the results of the current dissertation show how to integrate RRI into science education in a more grounded and meaningful way.

6.3 Limitations

The findings in this dissertation are subject to several limitations. In the following sections, the limitations of the studies will be described.

- Firstly, the sample of the **second and the third study**. The first point to address here was that teachers who taught a wide range of learners were included. For instance, the **second study** showed that the explanation for the RRI dimensions provided by the teachers who taught, e.g. in primary or upper secondary level differed slightly from one another. Thus, in order to apply the RRI model, attention should be given to the stage of the school where the model will be implemented. Secondly the data collection process of the **second study** was over three years, so that the processes in society may – in certain aspects – influence the respondents' answers. The third aspect

concerning the sample, was that only teachers were included. Although the researchers were participating in science classes and took pictures of the learners, the learners were not included in a sample.

- Secondly, the limitation addressed the instrument chosen for the **second study**. The interviews conducted with teachers concentrated on the teachers' explanations of the RRI dimensions. It happened during the interviewing that the initial explanation of some dimensions sounded too abstract for the informant and therefore an additional explanation was given by the interviewer, and the additional explanation somewhat influenced the answers of the informants. Therefore, a more comprehensive validation of the instrument would have been reasonable.
- Thirdly, the nature of the **third study** should be addressed. The **third study** was ethnographic. The literature emphasizes that ethnographic study means to stay in a field for a long period of study (Creswell & Miller, 2000). Additionally Fetterman (2009) stresses that working with people over a longer time frame in their natural environment gives validity to a study. However, the aim of the **third study** was not to concentrate on one or two cases over a long period of time, but rather see the variety. Therefore, the researchers chose seven cases (three visits in each case) which provided the variety of the dataset.
- Fourthly, the dissertation was limited considering the dimension *sustainability* in science education. The dimension *sustainability* which was originally stated in the conceptual framework of RRI, was left out from the RRI model in science education due to the coherence of the model which did not allow the inclusion of such a wide-ranging concept as *sustainability*. The second explanation was that the limited extent of study did not allow the analysis of *sustainability* in the RRI context in science education.
- The fifth issue concerning the studies was the fragmented diary writing. This was partly due to a time constraint and partly to the unwillingness to voice thoughts at certain times during the doctoral studies.
- The sixth issue concerns the literature of RRI in education which together with the mentioned philosophies (NOS, SSI, IBL, CE) addresses also, e.g. the problem-based learning, SSIBL, citizen science, informal learning, praxis-oriented and real-world learning. However, this dissertation cannot provide a comprehensive review of these because of practical constraints.

6.4 Suggestions for future studies

This research has raised many questions in need of further investigation. It is recommended that further research is undertaken in the following areas:

- The branch *exploring* was studied more in depth. The future research should, therefore, concentrate on the investigation of the branches *sense-making* and

action-taking and relations between them. But also *sustainability* that was not considered in the present dissertation.

- The second suggestion for further studies would be to concentrate on gender issues which have been listed as one of the six keys of RRI in EC politics (Responsible Research and Innovation, 2012). There are studies that concern the gender issue in education (e.g., Botella et al., 2019), but the topic requires further development.
- Further data collection is required to include other parties besides the teachers, including learners, researchers or parents, and to conduct participatory research. The other parties would show the RRI from different perspectives and therefore enrich the data collected.
- In future investigations, it might be possible to analyse philosophies that were not considered in the present dissertation through the RRI model, e.g. the problem-based learning, citizen science, informal learning, praxis-oriented and real-world learning. The analysis would enable a strengthening of the RRI model in science education.
- There is also abundant room for further progress in using, besides abductive analysis, other data analysis methods, e.g. grounded theory or phenomenography. But also quantitative research methods would be interesting to consider, in order to measure the emergence of the RRI categories in science education with a greater sample size.

REFERENCES

Abd-El-Khalick, F. (2006). Over and over and over again: College students' views of nature of science. In L. B. Flick & N. Lederman (Eds.), *Scientific inquiry and nature of science: Implications for Teaching, Learning, and Teacher Education* (pp. 389–425). Dordrecht, Netherlands: Springer.

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education*, *82*(4), 417–436.

Abma, T. A., & Broerse, J. E. (2010). Patient participation as dialogue: Setting research agendas. *Health Expectations*, *13*(2), 160–173.

Adam, B. (2008). Future matters: Futures known, created and minded. *Twenty-First Century Society*, *3*(2), 111–116.

Adam, B., & Groves, C. (2011). Futures tended: Care and future-oriented responsibility. *Bulletin of Science, Technology & Society*, *31*(1), 17–27.

Akinsanya, C., & Williams, M. (2004). Concept mapping for meaningful learning. *Nurse Education Today*, *24*(1), 41–46.

Alvesson, M., & Skoldberg, K. (2018). *Reflexive Methodology: New Vistas for Qualitative Research* (Third Ed.). Thousand Oaks, CA: SAGE Publications Ltd.

Anastopoulou, S., Sharples, M., Ainsworth, S., Crook, C., O'Malley, C., & Wright, M. (2012). Creating personal meaning through technology-supported science inquiry learning across formal and informal settings. *International Journal of Science Education*, *34*(2), 251–273.

Anyan, F. (2013). The Influence of Power Shifts in Data Collection and Analysis Stages: A Focus on Qualitative Research Interview. *The Qualitative Report*, *18*(18), 1–9.

Ariza, M. R., Abril, A. M., Quesada, A., & García, F. J. (2014). Bridging inquiry based learning and science education on socio scientific issues: Contributions to the PARRISE European Project. In L. Gómez Chova, A. López Martínez, & I. Candel Torres (Eds.), *INTED2014 Proceedings* (pp. 2599–2607). Valencia, Spain: IATED Academy.

Asante, K., Owen, R., & Williamson, G. (2014). Governance of new product development and perceptions of responsible innovation in the financial sector: Insights from an ethnographic case study. *Journal of Responsible Innovation*, *1*(1), 9–30.

Asveld, L., & van Dam-Mieras, R. (2017). Introduction: Responsible Research and Innovation for Sustainability. In L. Asveld, R. van Dam-Mieras, T. Swierstra, S. Lavrijssen, K. Linse, & J. van den Hoven (Eds.), *Responsible Innovation 3* (pp. 1–6). Cham, Switzerland: Springer.

Bardone, E., Burget, M., Saage, K., & Taaler, M. (2017). Making Sense of Responsible Research and Innovation in Science Education through Inquiry-based Learning. Examples from the Field. *Science Education International*, *28*(4), 293–304.

Bardone, E., & Lind, M. (2016). Towards a phronetic space for responsible research (and innovation). *Life Sciences, Society and Policy*, *12*(1), 1–18.

Berger, R. (2015). Now I see it, now I don't: Researcher's position and reflexivity in qualitative research. *Qualitative Research*, *15*(2), 219–234.

Berland, L. K., Schwarz, C. V., Krist, C., Kenyon, L., Lo, A. S., & Reiser, B. J. (2016). Epistemologies in practice: Making scientific practices meaningful for students. *Journal of Research in Science Teaching*, *53*(7), 1082–1112.

Biesta, G. J. (2015). *Beautiful risk of education*. New York, USA: Routledge.

Birks, M., Chapman, Y., & Francis, K. (2008). Memoing in qualitative research: Probing data and processes. *Journal of Research in Nursing*, *13*(1), 68–75.

Bivins, T. (2006). Responsibility and accountability. In K. R. Fitzpatrick & C. Bronstein (Eds.), *Ethics in Public Relations: Responsible Advocacy* (pp. 19–38). Thousand Oaks, CA: SAGE Publications Ltd.

Blok, V., & Lemmens, P. (2015). The emerging concept of responsible innovation. Three reasons why it is questionable and calls for a radical transformation of the concept of innovation. In B. Koops, I. Oosterlaken, H. Romijn, T. Swierstra, & J. van den Hoven (Eds.), *Responsible Innovation 2* (pp. 19–35). Cham, Switzerland: Springer.

Botella, C., Rueda, S., López-Iñesta, E., & Marzal, P. (2019). Gender Diversity in STEM Disciplines: A Multiple Factor Problem. *Entropy*, *21*(1), 1–17.

Bozeman, B., Rimes, H., & Youtie, J. (2015). The evolving state-of-the-art in technology transfer research: Revisiting the contingent effectiveness model. *Research Policy*, *44*(1), 34–49.

Bremer, S., Millar, K., Wright, N., & Kaiser, M. (2015). Responsible techno-innovation in aquaculture: Employing ethical engagement to explore attitudes to GM salmon in Northern Europe. *Aquaculture*, *437*, 370–381.

Brinkmann, S., & Kvale, S. (2005). Confronting the ethics of qualitative research. *Journal of Constructivist Psychology*, *18*(2), 157–181.

Buckley, N., Tassone, V. C., & Eppink, H. J. (2016). *Initial Review of Responsible Research and Innovation aspects in higher education curricula in Europe: Consultation and analysis of needs*. Retrieved from https://www.livingknowledge.org/fileadmin/Dateien-Living-Knowledge/Dokumente_Dateien/EnRRICH/D2.1_Initial_review_of_RRI_aspects_in_HE_curricula_in_Europe_-_consultation_and_analysis_of_needs.pdf

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

Burget, M., Bardone, E., & Pedaste, M. (n.d.). The RRI Map: Making sense of Responsible Research Innovation in Science Education. *Unpublished Manuscript*.

Burget, M., Bardone, E., Pedaste, M., & Saage, K. (2018). Science teachers' perceptions of the emergence of Responsible Research and Innovation in school. *Journal of Baltic Science Education*, *17*(4), 590–604.

Carter, L., Rodriguez, C. C., & Jones, M. (2014). Transformative Learning in Science Education: Investigating Pedagogy for Action. In J. L. Bencze & S. Alsop (Eds.), *Activist science and technology education* (pp. 531–545). Dordrecht, Netherlands: Springer.

Cartieri, F., & Potochnik, A. (2014). Toward Philosophy of Science's Social Engagement. *Erkenntnis*, *79*(5), 901–916.

Chilvers, J. (2010). *Sustainable Participation? Mapping out and reflecting on the field of public dialogue on science and technology*. Retrieved from https://ueaeprints.uea.ac.uk/37545/

Chilvers, J. (2013). Reflexive engagement? Actors, learning, and reflexivity in public dialogue on science and technology. *Science Communication*, *35*(3), 283–310.

Chu, S. K. W., Reynolds, R. B., Tavares, N. J., Notari, M., & Lee, C. W. Y. (2017). *21st century skills development through inquiry-based learning*. Singapore: Springer.

Cook-Sather, A. (2010). Students as learners and teachers: Taking responsibility, transforming education, and redefining accountability. *Curriculum Inquiry*, *40*(4), 555–575.

Corbin, J., & Strauss, A. (2014). *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory* (Fourth Ed.). Los Angeles: SAGE Publications, Inc.

Costello, G. J. (2019). The Philosophy of Innovation in Management Education: A Study Utilising Aristotle's Concept of Phronesis. *Philosophy of Management*, 1–16.

Creswell, J. W. (1998). *Qualitative inquiry and research design: Choosing among five tradition*. Thousand Oaks, CA: SAGE Publications Ltd.

Creswell, J. W., & Miller, D. L. (2000). Determining validity in qualitative inquiry. *Theory into Practice*, *39*(3), 124–130.

Dagher, Z. R., & Erduran, S. (2016). Reconceptualizing the nature of science for science education. In S. Erduran & Z. Dagher (Eds.), *Science & Education* (Vol. 25, pp. 147–164). Dordrecht, Netherlands: Springer.

Davis, M., & Laas, K. (2014). "Broader Impacts" or "Responsible Research and Innovation"? A Comparison of Two Criteria for Funding Research in Science and Engineering. *Science and Engineering Ethics*, *20*(4), 963–983.

de Bakker, E., de Lauwere, C., Hoes, A.-C., & Beekman, V. (2014). Responsible research and innovation in miniature: Information asymmetries hindering a more inclusive 'nanofood' development. *Science and Public Policy*, *41*(3), 294–305.

De Martino, M., Errichiello, L., Marasco, A., & Morvillo, A. (2013). Logistics innovation in seaports: An inter-organizational perspective. *Research in Transportation Business & Management*, *8*, 123–133.

De Saille, S. (2015). Innovating innovation policy: The emergence of "responsible research and innovation." *Journal of Responsible Innovation*, *2*(2), 152–168.

de Vocht, M., & Laherto, A. (2017). Profiling Teachers Based on Their Professional Attitudes towards Teaching Responsible Research and Innovation. *European Journal of Science and Mathematics Education*, *5*(3), 271–284.

de Vocht, M., Laherto, A., & Parchmann, I. (2014). Teachers' concerns and interests about teaching of "Responsible Research and Innovation" – Applying the Concerns-Based Adoption Model. In P. Hästö & H. Silfverberg (Eds.), *Proceedings of the Annual symposium of the Finnish Mathematics and Science Education Research Association* (pp. 103–114). Oulu, Finland: Finnish Mathematics and Science Education Research Association.

Denzin, N. K., & Lincoln, Y. S. (Eds.). (2017). *The SAGE Handbook of Qualitative Research* (Fifth Ed.). Thousand Oaks, CA: Sage Publications, Inc.

Dubois, A., & Gadde, L.-E. (2002). Systematic combining: An abductive approach to case research. *Journal of Business Research*, *55*(7), 553–560.

Erduran, S., & Dagher, Z. R. (2014). Reconceptualizing Nature of Science for Science Education. In S. Erduran & Z. R. Dagher (Eds.), *Reconceptualizing Nature of Science for Science Education* (pp. 1–18). Dordrecht, Netherlands: Springer.

European Commission (2002). Decision No 1513/2002/EC of the European Parliament and of the Council of 27 June 2002. Retrieved from https://publications.europa.eu/en/publication-detail/-/publication/5a016937-b81d-41ca-aac5-1b5bedd26f46/language-en

European Commission. (2014). Responsible Research and Innovation: Europe's Ability to Respond to Societal Challenges. Retrieved from https://ec.europa.eu/research/swafs/pdf/pub_rri/KI0214595ENC.pdf

European Parliament. (2013). Regulation EU No 1291/2013 of the European Parliament and of the Council of 11 December 2013 establishing Horizon 2020–the framework program for research and innovation (2014–2020). Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32013R1291

Evagorou, M., & Mauriz, B. P. (2017). Engaging elementary school pre-service teachers in modeling a socioscientific issue as a way to help them appreciate the social aspects of science. *International Journal of Education in Mathematics, Science and Technology*, *5*(2), 113–123.

Felt, U. (2014). Within, Across and Beyond: Reconsidering the Role of Social Sciences and Humanities in Europe. *Science as Culture*, *23*(3), 384–396.

Ferguson, R. (2011). Meaningful learning and creativity in virtual worlds. *Thinking Skills and Creativity*, *6*(3), 169–178.

Ferri, F., Dwyer, N., Raicevich, S., Grifoni, P., Altiok, H., Andersen, H. T., … Corallo, A. (2018). *Responsible Research and Innovation Actions in Science Education, Gender and Ethics: Cases and Experiences* (First Ed.). Cham, Switzerland: Springer.

Fetterman, D. M. (2009). *Ethnography: Step-by-Step* (Third Ed.). Los Angeles: SAGE Publications, Inc.

Feynman, R. P. (2005). *The Meaning of It All: Thoughts of a Citizen-Scientist*. New York, USA: Basic Books.

Fisher, E., & Rip, A. (2013). Responsible Innovation: Multi-Level Dynamics and Soft Intervention Practices. In R. Owen, J. Bessant, & M. Heintz (Eds.), *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society* (pp. 165–183). United Kingdom: John Wiley & Sons, Ltd.

Flipse, S. M., & Bayram-Jacobs, D. (2016). RRI Bridges Science Education and Communication. In M. C. A. van der Sanden & M. J. de Vries (Eds.), *Science and Technology Education and Communication* (pp. 147–162). Rotterdam, Boston, Taipei: Sense Publishers.

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

Forsberg, E.-M., Quaglio, G., O'Kane, H., Karapiperis, T., Van Woensel, L., & Arnaldi, S. (2015). Assessment of science and technologies: Advising for and with responsibility. *Technology in Society*, *42*, 21–27.

Frewer, L. J., Gupta, N., George, S., Fischer, A. R. H., Giles, E. L., & Coles, D. (2014). Consumer attitudes towards nanotechnologies applied to food production. *Trends in Food Science & Technology*, *40*(2), 211–225.

Ganon-Shilon, S., & Schechter, C. (2017). Making sense of school leaders' sense-making. *Educational Management Administration & Leadership*, *45*(4), 682–698.

García-Carmona, A., & Acevedo-Díaz, J. A. (2018). The Nature of Scientific Practice and Science Education. *Science & Education*, *27*(5–6), 435–455.

Geboers, E., Geijsel, F., Admiraal, W., & Dam, G. (2013). Review of the effects of citizenship education. *Educational Research Review*, *9*, 158–173.

Gianni, R. (2018). The discourse of responsibility: A social perspective. In R. Gianni, J. Pearson, & R. Bernard (Eds.), *Responsible Research and Innovation* (pp. 25–48). NY: Routledge.

Gifford, C., & Gomez, C. T. (2014). *Citizenship Education in Europe: The Expert's View*. London: Erasmus Academic Network.

Gilbert, N., & Stoneman, P. (Eds.). (2016). *Researching Social Life* (Fourth Ed.). Los Angeles: SAGE Publications Ltd.

Grinbaum, A., & Groves, C. (2013). What is "responsible" about responsible innovation? Understanding the ethical issues. In R. Owen, J. Bessant, & M. Heintz (Eds.), *Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society* (pp. 119–142). UK: John Wiley & Sons, Ltd.

Grunwald, A. (2009). Technology assessment: Concept and methods. In D. M. Gabby, A. W. M. Meijers, J. Woods, & P. Thagard (Eds.), *Philosophy of Technology and Engineering Sciences* (Vol. 9, pp. 1103–1146). Amsterdam, North Holland: Elsevier.

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

Hadjichambis, A. C., Georgiou, Y., Paraskeva Hadjichambi, D., Kyza, E. A., Agesilaou, A., & Mappouras, D. (2018). Promoting RRI and active citizenship in an inquiry-based controversial socio-scientific issue: The case of cholesterol regulation with statins. *Journal of Biological Education*, 1–13.

Halcomb, E. J., & Davidson, P. M. (2006). Is verbatim transcription of interview data always necessary? *Applied Nursing Research*, *19*(1), 38–42.

Harré, R. (1985). *The Philosophies of Science*. Oxford: Oxford University Press.

Hazelkorn, E., Ryan, C., Beernaert, Y., Constantinou, C. P., Deca, L., Grangeat, M., … Welzel, M. (Eds.). (2015). *Science education for responsible citizenship: Report to the European Commission of the Expert Group on Science Education*. Luxembourg: Publications Office of the European Union.

Heras, M., & Ruiz-Mallén, I. (2017). Responsible research and innovation indicators for science education assessment: How to measure the impact? *International Journal of Science Education*, *39*(18), 2482–2507.

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.

Hodson, D. (2014). Learning science, learning about science, doing science: Different goals demand different learning methods. *International Journal of Science Education*, *36*(15), 2534–2553.

Horsburgh, D. (2003). Evaluation of qualitative research. *Journal of Clinical Nursing*, *12*(2), 307–312.

Jacob, K., Van Den Hoven, J., Nielsen, L., Roure, F., Rudze, L., Stilgoe, J., … Riera, C. M. (2013). *Options for strengthening responsible research and innovation: Report of the expert group on the state of the art in Europe on responsible research and innovation*. Brussels: European Commission.

Johnson, M. (1999). Observations on positivism and pseudoscience in qualitative nursing research. *Journal of Advanced Nursing*, *30*(1), 67–73.

Josselson, R. (2013). *Interviewing for Qualitative Inquiry: A Relational Approach* (First Ed.). New York: The Guilford Press.

Kaberman, Z., & Dori, Y. J. (2009). Question posing, inquiry, and modeling skills of chemistry students in the case-based computerized laboratory environment. *International Journal of Science and Mathematics Education*, *7*(3), 597–625.

Kazempour, M. (2009). Impact of inquiry-based professional development on core conceptions and teaching practices: A case study. *Science Educator*, *18*(2), 56–68.

Kearney, C. (2016). *Efforts to increase students' interest in pursuing science, technology, engineering and mathematics studies and careers. National Measures taken by 30 Countries – 2015 Report*. Brussels, Belgium: European Schoolnet.

Keeble, B. R. (1988). The Brundtland report: 'Our common future.' *Medicine and War*, *4*(1), 17–25.

Kera, D. (2014). Innovation regimes based on collaborative and global tinkering: Synthetic biology and nanotechnology in the hackerspaces. *Technology in Society*, *37*, 28–37.

Kirch, S. A. (2010). Identifying and resolving uncertainty as a mediated action in science: A comparative analysis of the cultural tools used by scientists and elementary science students at work. *Science Education*, *94*(2), 308–335.

Klaassen, P., Kupper, F., Vermeulen, S., Rijnen, M., Popa, E., & Broerse, J. (2017). The Conceptualization of RRI: An Iterative Approach. In L. Asveld, R. van Dam-Mieras, T. Swierstra, S. Lavrijssen, K. Linse, & J. van den Hoven (Eds.), *Responsible Innovation 3: A European Agenda?* (pp. 69–92). Cham, Switzerland: Springer.

Kovács, G., & Spens, K. M. (2005). Abductive reasoning in logistics research. *International Journal of Physical Distribution & Logistics Management*, *35*(2), 132–144.

Kupper, J. F. H., Klaassen, P., Rijnen, M., Vermeulen, S., & Broerse, J. E. W. (2015). *Report on the quality criteria of Good Practice Standards in RRI*. Netherlands: VU University Amsterdam.

Laherto, A., Kampschulte, L., de Vocht, M., Blonder, R., Akaygun, S., & Apotheker, J. (2018). Contextualizing the EU's "Responsible Research and Innovation" Policy in Science Education: A Conceptual Comparison with the Nature of Science Concept and Practical Examples. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(6), 2287–2300.

Lederman, N., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, *39*(6), 497–521.

Lederman, N., & Zeidler, D. L. (1987). Science teachers' conceptions of the nature of science: Do they really influence teaching behavior? *Science Education*, *71*(5), 721–734.

Levidow, L., & Neubauer, C. (2014). EU research agendas: Embedding what future? *Science as Culture*, *23*(3), 397–412.

Levinson, R., & Consortium. (2017). Socio-scientific Inquiry-Based Learning: Taking off from STEPWISE. In L. Bencze (Ed.), *Science and Technology Education Promoting Wellbeing for Individuals, Societies and Environments* (pp. 477–502). Cham, Schwizerland: Springer.

Levitt, H. M. (2015). Qualitative psychotherapy research: The journey so far and future directions. *Psychotherapy*, *52*(1), 31–37.

Levitt, H. M., Bamberg, M., Creswell, J. W., Frost, D. M., Josselson, R., & Suárez-Orozco, C. (2018). Journal article reporting standards for qualitative primary, qualitative meta-analytic, and mixed methods research in psychology: The APA Publications and Communications Board task force report. *American Psychologist*, *73*(1), 26.

Levitt, H. M., Motulsky, S. L., Wertz, F. J., Morrow, S. L., & Ponterotto, J. G. (2017). Recommendations for designing and reviewing qualitative research in psychology: Promoting methodological integrity. *Qualitative Psychology*, *4*(1), 2–22.

Lucas, J. R. (1995). *Responsibility*. Oxford: Clarendon Press.

Lundström, M., Sjöström, J., & Hasslöf, H. (2017). Responsible Research and Innovation in Science Education: The Solution or The Emperor's New Clothes? *Sisyphus: Journal of Education*, *3*(5), 11–27.

Maass, K., Doorman, M., Jonker, V., & Wijers, M. (2019). Promoting active citizenship in mathematics teaching. *ZDM*, 1–13.

Mäeots, M. (2014). *Inquiry-based learning in a web-based learning environment: A theoretical framework of inquiry-based learning processes* (PhD Thesis, University of Tartu). Retrieved from https://pdfs.semanticscholar.org/3b9e/9a5df2550de5f7555d901cec7e48b43f3180.pdf

Majorek, M., & du Vall, M. (2018). Empowering civil society through educating about responsible research and innovation. In E. Masal, I. Önder, H. Çalişkan, & S. Beşoluk (Eds.), *SHS Web of Conferences* (Vol. 48, pp. 1–8). Istanbul, Turkey: EDP Sciences.

Marjanovic, O. (2013). Organizational Design of Innovative Education—Insights from a Combined Design and Action Research Project. In J. VomBrocke, R. Hekkala, S. Ram, & M. Rossi (Eds.), *Design Science at the Intersection of Physical and Virtual Design* (Vol. 7939, pp. 212–227). Berlin: Springer-Verlag Berlin.

McComas, W. F., Clough, M. P., & Almazroa, H. (1998). The role and character of the nature of science in science education. In B. Bell, R. Duit, K. Fisher, B. Fraser, C. Hsiung, D. Jorde, … P. Tamir (Eds.), *The Nature of Science in Science Education* (pp. 3–39). USA: Kluwer Academic Publishers.

McLeod, J. (2017). Reframing responsibility in an era of responsibilisation: Education, feminist ethics. *Discourse: Studies in the Cultural Politics of Education*, *38*(1), 43–56.

Mejlgaard, N., Christensen, M. V., Strand, R., Buljan, I., Carrió, M., Cayetano i Giralt, M., … Wuketich, M. (2018). Teaching Responsible Research and Innovation: A Phronetic Perspective. *Science and Engineering Ethics*, *25*(2), 1–19.

Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction—what is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, *47*(4), 474–496.

Morrow, S. L. (2005). Quality and trustworthiness in qualitative research in counseling psychology. *Journal of Counseling Psychology*, *52*(2), 250.

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

National curriculum for basic school [Põhikooli riiklik õppekava]. (2011). RT I, 14.02.2018, 8. Retrieved from https://www.riigiteataja.ee/akt/114022018008

National curriculum for basic schools and upper secondary schools [Põhikooli ja gümnaasiumi riiklik õppekava]. (2002). RT I 2002, 20, 116. Retrieved from https://www.riigiteataja.ee/akt/13276017

National curriculum for upper secondary schools [Gümnaasiumi riiklik õppekava]. (2011). RT I, 14.02.2018, 9. Retrieved from https://www.riigiteataja.ee/akt/114022018009

Noddings, N. (2006). *The Challenge to Care in Schools: An Alternative Approach to Education* (Second Ed.). New York, London: Teachers College Press.

Nulli, M., & Stahl, B. (2018). RRI in Higher Education. *ORBIT Journal*, *1*(4), 1–8.

Oftedal, G. (2014). The role of philosophy of science in Responsible Research and Innovation (RRI): The case of nanomedicine. *Life Sciences, Society and Policy*, *10*(1), 1–12.

Okada, A., Kowalski, R. P. G., Kirner, C., & Torres, P. L. (2019). Factors influencing teachers' adoption of AR inquiry games to foster skills for Responsible Research and Innovation. *Interactive Learning Environments*, *27*(3), 324–335.

Okada, A., & Sherborne, T. (2018). Equipping the Next Generation for Responsible Research and Innovation with Open Educational Resources, Open Courses, Open

Communities and Open Schooling: An Impact Case Study in Brazil. *Journal of Interactive Media in Education*, *1*(18), 1–15.

Teacher's professional standard [Õpetaja kutsestandardid]. (2019). Retrieved from http://www.opetajateliit.ee/?page_id=1057

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., Fisher, E., & Guston, D. (2013). A Framework for Responsible Innovation. In R. Owen, J. Bessant, & M. Heintz (Eds.), *Responsible Innovation: Managing the responsible emergence of science and innovation in society* (pp. 27–50). Chichester, UK: John Wiley & Sons, Ltd.

Patton, M. Q. (1990). *Qualitative evaluation and research methods*. Thousand Oaks, CA: Sage Publications, Inc.

Pavie, X. (2017). From responsible-innovation to innovation-care: Beyond constraints, a holistic approach of innovation. In R. Gianni, J. Pearson, & B. Reber (Eds.), *Responsible Research and Innovation: From concepts to practices* (pp. 245–267). Oxford: Routledge.

Pedaste, M., Mäeots, M., Siiman, L. A., De Jong, T., Van Riesen, S. A., Kamp, E. T., … Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review*, *14*, 47–61.

Pellizzoni, L. (2004). Responsibility and environmental governance. *Environmental Politics*, *13*(3), 541–565.

Pink, S. (2001). *Doing Visual Ethnography: Images, Media and Representation in Research* (First Ed.). California, Thousand Oaks: SAGE Publications, Ltd.

Rahman, M. S. (2017). The Advantages and Disadvantages of Using Qualitative and Quantitative Approaches and Methods in Language "Testing and Assessment" Research: A Literature Review. *Journal of Education and Learning*, *6*(1), 102–112.

Ratinen, I., Kähkönen, A.-L., & Lindell, A. (2018). Pupils' Understanding about Responsible Research and Innovation. *International Journal of Environmental and Science Education*, *13*(2), 143–154.

Reber, B. (2018). Taking moral responsibility seriously to foster Responsible Research and Innovation. In R. Gianni, J. Pearson, & B. Reber (Eds.), *Responsible Research and Innovation* (pp. 64–88). NY: Routledge.

Ribeiro, B., Bengtsson, L., Benneworth, P., Bührer, S., Castro-Martínez, E., Hansen, M., & Shapira, P. (2018). Introducing the dilemma of societal alignment for inclusive and responsible research and innovation. *Journal of Responsible Innovation*, *5*(3), 316–331.

Ribeiro, B., Smith, R. D. J., & Millar, K. (2017). A Mobilising Concept? Unpacking Academic Representations of Responsible Research and Innovation. *Science and Engineering Ethics*, *23*(1), 81–103.

Robinson, D. (2009). Co-evolutionary scenarios: An application to prospecting futures of the responsible development of nanotechnology. *Technological Forecasting and Social Change*, *76*(9), 1222–1239.

Roco, M. C., Harthorn, B., Guston, D., & Shapira, P. (2011). Innovative and responsible governance of nanotechnology for societal development. In M. C. Roco, C. A. Mirkin, & M. C. Hersam (Eds.), *Nanotechnology Research Directions for Societal Needs in 2020* (pp. 561–617). Dordrecht, Heidelberg, London, New York: Springer.

Rodgers, C. (2002). Defining Reflection: Another Look at John Dewey and Reflective Thinking. *Teachers College Record*, *104*(4), 842–866.

Romero-Ariza, M., Abril, A. M., & Quesada, A. (2017). Design and evaluation of teaching materials for Responsible Research and Innovation. *Sisyphus-Journal of Education*, *5*(3), 28–43.

Ruddick, S. (1995). *Maternal Thinking: Toward a Politics of Peace*. Boston: Beacon Press.

Ruggiu, D. (2015). Anchoring European Governance: Two Versions of Responsible Research and Innovation and EU Fundamental Rights as 'Normative Anchor Points.' *NanoEthics*, *9*(3), 217–235.

Sadler, T. D., Chambers, F. W., & Zeidler, D. L. (2004). Student conceptualizations of the nature of science in response to a socioscientific issue. *International Journal of Science Education*, *26*(4), 387–409.

Schedler, A. (1999). Conceptualizing accountability. In A. Schedler, L. J. Diamond, & M. F. Plattner (Eds.), *The Self-restraining State: Power and Accountability in New Democracies* (pp. 13–28). London: Lynne Rienner Publishers.

Scholten, V., van den Hoven, J., Cuppen, E., & Flipse, S. (2016). Science communication and Responsible Research and Innovation. How can they complement each other? *JCOM*, *15*(6), 1–7.

Schulz, W., Ainley, J., Fraillon, J., Losito, B., Agrusti, G., & Friedman, T. (2016). *Becoming Citizens in a Changing World: IEA International Civic and Citizenship Education Study 2016 international report*. Amsterdam: Springer.

Setiawan, A. D., & Singh, R. (2015). Responsible innovation in practice: The adoption of solar PV in telecom towers in Indonesia. In B. Koops, I. Oosterlaken, H. Romijn, T. Swierstra, & J. van den Hoven (Eds.), *Responsible Innovation 2* (pp. 225–243). Cham, Switzerland: Springer.

Sharan, Y. (2015). Meaningful learning in the cooperative classroom. *Education 3–13*, *43*(1), 83–94.

Silverman, D. (2013). *Doing qualitative research: A practical handbook*. Los Angeles, London, New Delhi, Singapore, Washington DC: SAGE Publications, Ltd.

Simonneaux, L., & Simonneaux, J. (2009). Socio-scientific reasoning influenced by identities. *Cultural Studies of Science Education*, *4*(3), 705–711.

Sincer, I., Severiens, S., & Volman, M. (2019). Teaching diversity in citizenship education: Context-related teacher understandings and practices. *Teaching and Teacher Education*, *78*, 183–192.

Sparkes, A. C. (1998). Validity in qualitative inquiry and the problem of criteria: Implications for sport psychology. *The Sport Psychologist*, *12*(4), 363–386.

Sperling, E., Wilkinson, T., & Bencze, L. (2014). We got involved and we got to fix it!: Action-oriented school science. In J. Bencze & S. Alsop (Eds.), *Activist science and technology education* (pp. 365–380). Dordrecht, Netherlands: Springer.

Spronken-Smith, R., Walker, R., Batchelor, J., O'Steen, B., & Angelo, T. (2011). Enablers and constraints to the use of inquiry-based learning in undergraduate education. *Teaching in Higher Education*, *16*(1), 15–28.

Stahl, B. C. (2013). Responsible research and innovation: The role of privacy in an emerging framework. *Science and Public Policy*, *40*(6), 708–716.

Stavrou, D., Michailidi, E., & Sgouros, G. (2018). Development and dissemination of a teaching learning sequence on nanoscience and nanotechnology in a context of communities of learners. *Chemistry Education Research and Practice*, *19*(4), 1065–1080.

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

Stirling, A. (2010). Keep it complex. *Nature*, *468*(7327), 1029–1031.
Sutcliffe, H. (2011). *A report on Responsible Research & Innovation*. MATTER and the European Commission.
Sword, W. (1999). Accounting for presence of self: Reflections on doing qualitative research. *Qualitative Health Research*, *9*(2), 270–278.
Tassone, V. C., O'Mahony, C., McKenna, E., Eppink, H. J., & Wals, A. E. J. (2018). (Re-) designing higher education curricula in times of systemic dysfunction: A responsible research and innovation perspective. *Higher Education*, *76*(2), 337–352.
Tavory, I., & Timmermans, S. (2014). *Abductive Analysis: Theorizing Qualitative Research*. Chicago: University of Chicago Press.
Te Kulve, H., & Rip, A. (2011). Constructing productive engagement: Pre-engagement tools for emerging technologies. *Science and Engineering Ethics*, *17*(4), 699–714.
Thomas, E., & Magilvy, J. K. (2011). Qualitative rigor or research validity in qualitative research. *Journal for Specialists in Pediatric Nursing*, *16*(2), 151–155.
Timmermans, J. (2017). Mapping the RRI Landscape: An Overview of Organisations, Projects, Persons, Areas and Topics. In L. Asveld, R. van Dam-Mieras, T. Swierstra, S. Lavrijssen, K. Linse, & J. van den Hoven (Eds.), *Responsible Innovation 3* (pp. 21–47). Cham, Switzerland: Springer.
Tirre, F., Kampschulte, L., Thoma, G.-B., Höffler, T., & Parchmann, I. (2018). Design of a student lab program for nanoscience and technology–an intervention study on students' perceptions of the Nature of Science, the Nature of Scientists and the Nature of Scientific Inquiry. *Research in Science & Technological Education*, *37*(4), 1–26.
Trilling, B., & Fadel, C. (2009). *21st century learning skills*. San Francisco, CA: Jossey-Bass.
Ulnicane, I. (2016). "Grand Challenges" concept: A return of the "big ideas" in science, technology and innovation policy? *International Journal of Foresight and Innovation Policy*, *11*(1/2/3), 5–21.
Urban, M., Vandenbroeck, M., Laere, K. V., Lazzari, A., & Peeters, J. (2012). Towards Competent Systems in Early Childhood Education and Care. Implications for Policy and Practice. *European Journal of Education*, *47*(4), 508–526.
van de Poel, I., & Sand, M. (2018). Varieties of responsibility: Two problems of responsible innovation. *Synthese*, 1–19.
van der Horst, S. (2018). *Designing a tool to stimulate reflexivity of fundamental scientists using a novel co-design approach* (Master thesis, Delft University of Technology). Retrieved from https://repository.tudelft.nl/islandora/object/uuid:073cc8a8-27a3-4004-ae65-f4590e3d732e?collection=education
van der Meij, M. G., Broerse, J. E., & 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.
Van Joolingen, W. R., De Jong, T., & Dimitrakopoulou, A. (2007). Issues in computer supported inquiry learning in science. *Journal of Computer Assisted Learning*, *23*(2), 111–119.
van Uum, M. S., Verhoeff, R. P., & Peeters, M. (2017). Inquiry-based science education: Scaffolding pupils' self-directed learning in open inquiry. *International Journal of Science Education*, *39*(18), 2461–2481.
Vasen, F. (2017). Responsible innovation in developing countries: An enlarged agenda. In L. Asveld, R. van Dam-Mieras, T. Swierstra, S. Lavrijssen, K. Linse, & J. van den Hoven (Eds.), *Responsible Innovation 3* (pp. 93–109). Cham, Switzerland: Springer.

Vasquez Heilig, J., Ward, D. R., Weisman, E., & Cole, H. (2014). Community-based school finance and accountability: A new era for local control in education policy? *Urban Education*, *49*(8), 871–894.

Verhoeff, R. P. (2017). The Use of Drama in Socio-Scientific Inquiry-Based Learning. In K. Hahl, K. Juuti, J. Lampiselkä, A. Uitto, & J. Lavonen (Eds.), *Cognitive and Affective Aspects in Science Education Research* (pp. 117–126). Cham, Switzerland: Springer.

von Schomberg, R. (2011). *Towards responsible research and innovation in the information and communication technologies and security technologies fields*. Retrieved from https://philpapers.org/archive/VONTRR.pdf

Von Schomberg, R. (2013). A vision of responsible research and innovation. In R. Owen, J. Bessant, & M. Heintz (Eds.), *Responsible innovation: Managing the responsible emergence of science and innovation in society* (pp. 51–74). UK: John Wiley & Sons, Ltd.

Wang, J.-R., & Lin, S.-W. (2008). Examining reflective thinking: A study of changes in methods students' conceptions and understandings of inquiry teaching. *International Journal of Science and Mathematics Education*, *6*(3), 459–479.

Wilford, S. H. (2016). What is required of requirements?: A first stage process towards developing guidelines for responsible research and innovation. *ACM SIGCAS Computers and Society*, *45*(3), 348–355.

Wilsdon, J. (2005). Paddling upstream: New currents in European technology assessment. In M. Rodemeyer, D. Sarewitz, & J. Wilsdon (Eds.), *The Future of Technology Assessment* (pp. 22–29). Washington, DC: Woodrow Wilson International Center for Scholars.

Winter, G. (2000). A comparative discussion of the notion of "validity" in qualitative and quantitative research. *The Qualitative Report*, *4*(3), 1–14.

Wolcott, H. F. (2005). *The Art of Fieldwork*. United Kingdom: Rowman Altamira.

Zeidler, D. L., & Nichols, B. H. (2009). Socioscientific issues: Theory and practice. *Journal of Elementary Science Education*, *21*(2), 49.

Zeidler, D. L., Sadler, T. D., Simmons, M. L., & Howes, E. V. (2005). Beyond STS: A research-based framework for socioscientific issues education. *Science Education*, *89*(3), 357–377.

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*(1), 1–19.

APPENDICES

Appendix A.1. Protocol for the semi-structured interview with teachers about *responsibility*, *research* and *innovation* and *responsible research and innovation*

Date:
Interviewer:
Informant:
Length of service:
Age:
Subjects and grades:

QUESTIONS

The questions are divided into two groups. The first group contains questions that are related to *responsibility*, *research* and *innovation* and *responsible research and innovation*. The second group involves the definitions for the RRI dimensions explained for the teachers. The additional question with every dimension was about how to bring the dimension to the school context.

On *responsibility*, *research* and *innovation* and *responsible research and innovation*

(1) What role does science play in your everyday life?
(1) How can science be brought to school?
(2) What does innovation mean to you?
(3) How can innovation be brought to school?
(4) What does responsibility mean to you?
(5) How can responsibility be brought to school?
(6) What does responsible research and innovation mean to you?
(7) How can responsible research and innovation be brought to school?

Appendix A.2. Protocol for the semi-structured interview with teachers about RRI dimensions

The way RRI dimensions were explained to the teachers during the interview

(1) *Reflexivity* can be interpreted as discussing the values, needs and problems in society.
(2) *Responsiveness* can be explained as taking responsibility for the concerns or problems in a wider social context and taking appropriate action.
(3) *Anticipation* means foresensing and preventing the long-term impacts of research and innovation outcomes.
(4) *Inclusion* denotes including various parties in the research and innovation process at its early stages.
(5) *Sustainability* is described as a development path where the needs and efforts of the current generation are covered without limiting the interests of the future generations.
(6) *Care* is characterized by decisions that are connected to public interests and where a person is taking responsibility for own actions by themselves.

Post interview comments and/or observations:

Appendix B.1. Protocol for the semi-structured pre-interview with teachers about inquiry-based learning and RRI

Date:
Interviewer:
Informant:
Length of service:
Age:
Subjects and grades:

QUESTIONS

The questions are divided into two groups. The first group contains questions that are related to inquiry-based learning. The main function of these questions is to tap into the kind of conception, understanding, informal knowledge teachers have about inquiry-based learning. The second group of questions is devoted to investigating RRI-related issues. If teachers are not familiar with the notion of RRI (Responsible Research and Innovation), the questions are meant to bring out the way in which teachers treat issues and questions that are more related to the epistemological and social/ethical issue of inquiry.

On Inquiry-based Learning

(1) What is inquiry for you? What kind of associations this word triggers? Scientists do inquiries. What kind of image or conception do you have about their inquiries?
(2) Let us now come to inquiry-based learning as you practice it in your class. Do you think that inquiry-based learning can be compared with the way in which scientists conduct their own inquiries?
(3) Are there any significant differences? Are there any significant similarities? When you apply inquiry-based learning in your class, do you follow any specific approach or model?
(4) What is the role that personal experience plays in applying inquiry-based learning?

Appendix B.2. Protocol for the semi-structured interview with teachers about inquiry-based learning and RRI

On Responsible Research and Innovation

(1) In conducting an inquiry activity in your class do you also address issues or questions related to the broader meaning and significance of inquiry? If yes, which aspects do you consider important to discuss during your class?
(2) How do you think responsibility can be related to conducting an inquiry activity?
(3) Do you usually bring up ethical/social issues in case an inquiry activity gives you the opportunity to do so?
(4) Do you let your learners do inquiry activities individually or in groups?
(5) When you conduct an inquiry activity with your learners, do you involve other people outside of the class like older learners, university students, other teachers, parents, researchers, scientists, etc.?

Post interview comments and/or observations:

Appendix C. Research diary

(the extracts from the research diary are presented)

Date	Extracts from the diary
27.01.2018	To do science – sometimes it is so interesting. The mismatches occur and you want to discover, to get an answer to the question. It does not matter that you do not know, somewhere somebody can describe it or has written how to do. It is always interesting. I think this is the magic of science.
24.04.2018	Sometimes I have a feeling why am I here in academy? I am not satisfied with my writings, it is embarrassing to send them to the supervisors, but I can't do better. I picture in my mind that I belong in supervisors' opinion to the category „complicated".
06.05.2018	The data analysis is the continuous communication process with the data. Who are you as a researcher by this data, who are the informants and what are their estimates? Sometimes there are questions in my head, that when I interviewed did I ask all questions right? Concerning some informants the „ship" inclined like in one direction and concerning the other informants in other direction. This, however, was depending also on the time when I did the interviews, because also my opinions changed during the interviewing. Because when you ask something can you interpret these opinions for all others when you did not ask this directly from the others? Therefore, you are staying continuously like in the world of assumptions. From the little signs trying to read out the truth. But the truth from the different teachers' opinions is still more truth, than simply one teacher's opinion.
11.07.2018	When I entered to the doctoral studies, I suddenly felt as if I had opened the door and I was drewn with the abundance. During the doctoral studies I travelled in the conceptual chambers one more interesting than the other. This is exactly what gives the meaning for all of the learning period and leads from the superficial and ah-let's-do-something-mindset to the discovery of the deeper layers of science.
16.08.2018	The responsibility can't be taught in a top-down way, but this is something that should come from the teacher's self-analysis. What kind of teachers am I? In which aspects will I give the higher responsibility for the learners? In which aspects will I take the responsibility? Should me as a teachers know everything? Are there some topics in a lesson that are new to me that I can discover together with learners? *Uncertainty is a source for the personal changes.*

SUMMARY IN ESTONIAN

Vastutustundliku teaduse ja innovatsiooni mõistmine loodusteaduslikus hariduses

Vastutustundlik teadus ja innovatsioon (*Responsible Research and Innovation*, RRI) on muutunud viimasel kümnendil Euroopa Liidu teadus- ja innovatsioonipoliitika oluliseks osaks ning seda kasutatakse poliitilise raamistikuna teaduse juhtimisel (Forsberg et al., 2015). RRI korral kaasatakse eri osalisi teadus- ja innovatsiooniprotsessi juba varajases staadiumis, et selle tulemused vastaksid võimalikult suurel määral ühiskonna väärtustele ja vajadustele (Owen *et al.*, 2012). Ehkki viimasel kümnendil on teadus- ja arendustegevuses hakatud üha enam huvi tundma RRI kontseptuaalse käsitluse vastu, võib RRI peamiseks probleemiks pidada piiratud arusaama kontseptsiooni olemusest. Ka varasemates uurimustes on täheldatud, et RRI kontseptsioon on veel kujunemisjärgus (Blok & Lemmens, 2015; Oftedal, 2014; Zwart et al., 2014), ning kuna RRI hõlmab mitut distsipliini, on eri valdkondade teadlased kontseptsiooni omal viisil tõlgendanud (Klaassen *et al.*, 2017).

Niisamuti nagu teistes distsipliinides, ilmneb ka haridusvaldkonnas, et RRId ei ole tähendusrikkalt kontseptualiseeritud (Heras & Ruiz-Mallén, 2017). Euroopa Komisjon on ühe RRI võtmetegurina välja pakkunud loodusteadusliku hariduse ning uurimustes on analüüsitud, kuidas seda RRI kontekstis mõistetakse (European Commission, 2014; Laherto et al., 2018). Ebaselgeks jääb aga see, kuidas tuleks RRI laiemat teoreetilist käsitlust loodusteaduslikus hariduses tõlgendada ning RRId haridusvaldkonda tähendusrikkalt integreerida (Timmermans, 2017). Lisaks on varasemates haridusteaduslikes uurimustes RRId seotud eri suundadega, näiteks uurimusliku õppe (*inquiry-based learning*), sotsiaalteaduslike probleemide (*socio-scientific issues*), teaduse olemuse (*nature of science*) ja kodanikuharidusega (*citizenship education*; Evagorou & Mauriz, 2017; Laherto et al., 2018; Verhoeff, 2017), kuid neid suundi on käsitletud fragmenteeritult ning need ei moodusta tervikut. Eelkirjeldatud kitsaskohtadega tegelemiseks antakse doktoriväitekirjas ülevaade sellest, kuidas RRId on teaduskirjanduses käsitletud, näidatakse võimalusi, kuidas RRId hariduses tähendusrikkalt tõlgendada, ning pakutakse välja RRI mudel loodusteadusliku hariduse tarbeks.

Siinsel uurimistööl on neli eesmärki: 1) välja selgitada RRI definitsioonid ja kontseptuaalsed dimensioonid; 2) teha selgeks, kuidas loodusteaduste õpetajad tajuvad RRId oma töös; 3) välja selgitada, kuidas loodusteaduste õpetajad mõistavad vastutustundlikkuse tähendust uurimusliku õppe eri etappides; 4) käsitleda RRIga seotud filosoofilisi suundi omavahel seotuna ning esile tuua vastutustundlikkuse osa haridusfilosoofilistes suundades. Eelkirjeldatud eesmärkidest lähtudes sõnastati järgmised uurimisküsimused.

- Kuidas RRId defineeritakse ja kuidas avalduvad RRI kontseptuaalsed dimensioonid teaduskirjanduses?
- Kuidas loodusteaduste õpetajad tajuvad RRI avaldumist oma töös?

- Mis tähendus on terminil *vastutustundlikkus* uurimusliku õppe eri etappides?
- Kuidas kirjeldada RRIga seotud haridusfilosoofilisi suundi omavahel seotuna ning kuidas avaldub vastustundlikkus haridusfilosoofilistes suundades?

Esimeses uuringus (esimene uurimisküsimus) analüüsiti teaduskirjandust, kust leiti RRI definitsioonid ja dimensioonid. Seevastu teine ja kolmas uuring (teine ja kolmas uurimisküsimus) olid oma olemuselt empiirilised: teine uuring põhines intervjuudel 29 loodusteaduste õpetajaga ning kolmas, etnograafiline uuring, eel- ja järelintervjuudel seitsme loodusteaduste õpetajaga ning intervjuude vahel toimunud vaatlustel. Neljas uuring (neljas uurimisküsimus) pakkus teoreetilist ülevaadet haridusfilosoofilistest suundadest loodusteaduslikus hariduses ning nende seostest vastutustundlikkusega. Empiirilisi andmeid analüüsiti abduktiivse sisuanalüüsi meetodil, mis võimaldab arvesse võtta nii teoreetilist alust kui ka empiirilist andmestikku. Abduktiivsesse sisuanalüüsi kaasatakse elemendid, mida seni ei ole teooriaga seotud, ning luuakse interpretatsioonid uuritavast nähtusest (Tavory & Timmermans, 2014).

Esimeses uuringus tehtud kirjandusanalüüsist ilmnes, et administratiivseid – peamiselt Euroopa Liidu poliitikast tulenevaid – RRI definitsioone leidub teaduskirjanduses rohkelt, kuid need on tuletatud enamasti administratiivsetest definitsioonidest. Seetõttu on vaja rohkem empiirilisi uuringuid, mis annaksid võimaluse RRId sügavamalt mõista – kirjeldada RRId protsessina, kuhu kaasatakse osalisi demokraatlikult, nähes ette ja tajudes, kuidas teadus ja innovatsioon võivad või saavad toimida ühiskonna hüvanguks. Samuti selgus vastusena esimesele uurimisküsimusele, et RRId iseloomustatakse nelja kontseptuaalse dimensiooni ja kahe avalduva kontseptuaalse dimensiooni kaudu. Kontseptuaalsete dimensioonide eesmärk on täpsustada RRI üldist raamistikku ning võimaldada RRI mõiste sügavamast sisust aru saada (Stilgoe et al., 2013). Nende dimensioonide hulka kuuluvad kaasamine (*inclusion*), mis avaldub eri osaliste, nt kodanike, valitsuse, teadlaste ja ettevõtjate kaasamises ühiskonna protsessidesse (Asante et al., 2014; De Saille, 2015); ennetamine (*anticipation*), mis tähendab teadus- ja innovatsioonisaavutuste pikaajalisema mõju etteaimamist ning ennetamist (Owen et al., 2012); refleksiivsus (*reflexivity*), mis seisneb ühiskonna väärtuste ja vajaduste üle mõtisklemises ning reflekteerimises (Forsberg et al., 2015; Stilgoe et al., 2013); operatiivsus (*responsiveness*), mis väljendub reageerimises ühiskonna väärtustele ja vajadustele (Forsberg et al., 2015; Levidow & Neubauer, 2014; Stilgoe et al., 2013). Seevastu avalduvaid kontseptuaalseid dimensioone võib käsitleda kui RRIga seotud tulevikudimensioone: jätkusuutlikkust (*sustainability*) tõlgendatakse kui arenguteed, kus kaetakse praeguse põlvkonna vajadused ja püüdlused, seadmata ohtu tulevaste põlvkondade sarnaseid huve (Keeble, 1988), ning vastutustundlikkuse kui hoole (*responsibility as care*) all peetakse silmas otsuseid, mis on seotud avaliku huviga ja mille korral võtab inimene oma tegude eest ise vastutuse (Adam & Groves, 2011).

Doktoriväitekirja teine eesmärk oli teha selgeks, kuidas loodusteaduste õpetajad tajuvad RRI avaldumist oma töös. Eesmärgi saavutamiseks tehti teine uuring, mille väärtus seisneb teaduskirjanduse põhjal ilmnenud RRI dimensioonide

esmakordses interpreteerimises hariduse kontekstis. Uuringust ilmnes, et RRId kontseptualiseeriti haridusvaldkonnas järgmiste kategooriatena: arusaamine (*sense-making*), tegutsemine (*action-taking*), uurimine (*exploring*) ja kaasamine (*inclusion*). Arusaamist võib tõlgendada kui informatsiooni kogumist vastutustundlikult, teaduse ja innovatsiooniga seotud probleemide üle arutlemist ja reflekteerimist ning eetiliste aspektidega arvestamist. Tegutsemine väljendab reageeringuid ja toiminguid, mis on kooskõlas kogukonna (ühiskonna) väärtuste ja vajadustega, ning õppeprotsessis vastutuse võtmist keskkonna ja tehnoloogiliste vahendite eest. Uurimist tõlgendatakse uuringute tegemisena uurimusliku õppe tundides, kus tajutakse ka vastutuse tähendust uurimusliku õppe protsessis. Kaasamine tähendab eri osaliste kaasamist teadus- ja innovatsiooniprotsessi.

Töö kolmas eesmärk oli teada saada, mis tähendus on terminil *vastutustundlikkus* uurimusliku õppe eri etappides. Kolmas uuring võimaldas sügavuti tundma õppida teise uuringu kategooriat *uurimine*, millele lisandusid *vastutustundlikkus* ja *kaasamine*. Uuringu tulemusel jõuti järelduseni, et RRId saab haridusvaldkonnas tõlgendada kui tähendusrikast kaasamist nii uurimusliku õppe sees kui ka jaoks, mille korral antakse õpilastele võimalus teha tähendusrikkaid otsuseid uurimusliku õppe eri etappides ning seega võtta vastutus uurimusliku õppe protsessi eest.

Neljas eesmärk oli käsitleda RRIga seotud haridusfilosoofilisi suundi omavahel seotuna ning tuua esile vastutustundlikkuse osa nendes. Neljas uuring näitas, et RRId hariduses võib kirjeldada mudelina, kus õpilasi kaasatakse protsessi, andes neile võimaluse vastutada, ning õpilastel võimaldatakse teaduslikult põhjendatud teadmistest või tehnoloogiaga seotud protsessidest aru saada, nendega seoses tegutseda või neid uurida. Seega on RRI mudeli väärtus selle kõikehõlmavus, mis toob kokku eri haridusfilosoofilised suunad ning mis võimaldab neid suundi käsitada vastutustundlikkuse kui hoole aspektist lähtudes.

Eelkirjeldatud uurimistulemuste põhjal saab anda soovitusi õpetajatele. Et rakendada RRI mudelit efektiivselt, peaksid õpetajad analüüsima oma koolikogemust RRI mudelile tuginedes. Analüüsi oluline osa on vastutustundlikkuse mõtestamine enda jaoks, aga ka vastutuse võtmine ning jagamine enda ja õpilaste vahel. Selleks on vaja mõista sügavuti haridusfilosoofilisi suundi – teaduse olemust, uurimuslikku õpet, sotsiaalteaduslikke probleeme ja kodanikuteadust − ning vaheldada neid oskuslikult, võttes arvesse õppeprotsessi eesmärki. Uurimistulemustest ilmnes ka vajadus luua RRI kogukond, mis toetaks RRI rakendamist haridusvaldkonnas. Kogukonna loomine võimaldaks kaasata tegevustesse ka teadlasi, kes saaksid teha teaduse olemuse õpetajatele ja teistele huvipooltele paremini mõistetavaks. Edaspidi võib teha katset rakendada RRI mudelit kui tervikut peale üldhariduskooli ka koolieelses lasteasutuses, kutsekoolis või ülikoolis.

Doktoritöö raames saab anda soovitusi ka õppekava arendajatele ja poliitikutele. On tähtis, et õppekava arendajad seletaksid vastutustundlikkuse mõiste õppekavas või õpetajatele pakutavates lisamaterjalides selgemalt ja arusaadavamalt lahti, et õpetajad aduksid seda ühtmoodi. Eesti põhikooli ja gümnaasiumi õppekavas on vastutustundlikkuse mõistet küll kirjeldatud, kuid seda ei ole

piisavalt avatud. RRI integreerimine haridusse nõuab ka õppekava toetavate õppematerjalide ja koolituste väljatöötamist. Seevastu poliitikakujundajatele pakub uuring teadmist, et RRId ei tuleks vaadelda üksnes poliitilise mõõtevahendina, vaid tõenduspõhise kontseptsioonina, mida saab loodusteaduslikku haridusse integreerida tähendusrikkal viisil.

ACKNOWLEDGEMENTS

In the current paragraph I want to thank people who have been together with me in my PhD journey.

First and foremost I want to thank my supervisors Emanuele Bardone and Prof. Margus Pedaste. You both are very different supervisors concerning your way of supervising and world view, but you both are in my opinion the world's greatest supervisors. I owe a debt of gratitude to trust and providing enormous support. My special thanks for your advice during my studies because it lead to the knowledge that good supervising is a basis for the good science.

A very special thank you goes out to my family – my three little sons Mehis, Maanus and Malev and to my husband Meelis. During my doctoral study I gave birth to my two younger sons and created a home with my husband. In spite of tough times we have overcome of difficulties and achieved much in a short time. Thank you for supporting and being always with me!

I also want to express my gratitude to all teachers who participated in my studies. Thank you for devoting time although in times it was not so easy. I have heard the interview conversations and read the transcriptions over and over and these have been so encouraging and inspiring. I am still amazed how wonderful teachers work in our schools! Your experience grounded a basis to learn a lot. My special gratitude is also extended to Katrin Saage who was my co-fellow in the second and third study and would be definitely my favourite teacher at school. Thank you for showing me the ways what the term responsibility in education really means and teach science passionately.

There were are also multitude of individuals who helped me to arrive to this point. Thank you, my fellow doctoral students! My warmest thanks go to Laura Kirss, Gerli Silm, Raili Allas, Pihel Hunt, Liina Adov and Liina Malva for feedback, interesting conversations and support; Külli Kori for providing the valuable hints during my study. I also want to express my gratitude to the fellow students in Estonia and abroad with whom I have participated in conferences, writing groups, summer and winter schools of doctoral students. Thank you for giving me a valuable feedback and thinking along with me! Thanks also to the members of the Facebook groups „PhD and early career researcher parents", and „Doctoral students of educational science in TU" for providing me support and sharing the guidelines for my studies. I also would like offer my special thanks to Paul Emmet and Riina Reinsalu for the grammatical corrections.

My warmest thanks also go to the centre of educational technology. Thank you for the support, unforgettable moments and being as a family to me.

I would not have been able to afford to undertake this endeavour without the fantastic researchers Prof. Robert-Jan Simons, Prof. Dr. Angelika Paseka, Jelena Radisic, Prof. James Groccia, Prof. Alexandar Baucal, Prof. Äli Leijen Olev Must, Liina Lepp, Ester Bardone and many others. Thank you for offering the valuable advice during my studies! I am grateful for the addmission comittee – Prof. Miia Rannikmäe, Prof. Jack Holbrook, Prof. Jaan Kõrgesaar, Prof. Edgar

Krull – who accepted me as a PhD candidate and believed in me, my journey would have not started without your trust.

My gratitude is also extended to the following funding bodies: European Commission, European Regional Development Fund, Estonian Students Fund in USA, Kristjan Jaak Scholarship Programme and Tartu City Governance. I also bow to you Triin Viltrop from Naiskodukaitse and Karin Klaus from sorority Indla for helping me with the funding bodies.

Dixi et salvavi animam meam.

PUBLICATIONS

CURRICULUM VITAE

Name: Mirjam Burget
Work address: Centre for Educational Technology, Institute of Education, University of Tartu, Salme 1a, Tartu, 50103, Estonia
Telephone: +372 5343 2408
E-mail: mirjam.burget@ut.ee

Education:

2014–	University of Tartu, Institute of Education, PhD studies in Educational Science
2009–2011	University of Tartu, Faculty of Science and Technology, masters degree (MA), Teacher of Biology
2005–2006	Leibniz University Hannover, exchange student (Erasmus program)
2001–2006	Estonian University of Life Sciences, Faculty of Forestry and Rural Engineering, bachelor degree (BA), Natural Resource Management
1999–2001	Pärnumaa Vocational Education Centre, Social Care
1996–1999	Pärnu Raeküla Gymnasim

Professional development:

2018–…	University of Tartu, Institute of Education, Junior researcher of educational technology
2013–2017	University of Tartu, Institute of Education, Specialist of educational technology
2013	University of Tartu, Faculty of Science and Technology, Specialist of communication
2013–2014	Foundation Tartu Environmental Education Centre, Environmental media teacher
2009–2014	Foundation Tartu Environmental Education Centre, Project manag
2008–2014	Foundation Tartu Environmental Education Centre, Project manager
2008–2014	Foundation Tartu Environmental Education Centre, Specialist of environmental information
2006–2007	ERKAS Pärnu Institute OÜ, Landscape planner

Field of research: Responsible Research and Innovation in education

Publications:

- Burget, M., Bardone, E., & Pedaste, M. (n.d.). The RRI Map: Making sense of Responsible Research Innovation in Science Education. *Unpublished Manuscript.*
- Burget, M., Bardone, E., Pedaste, M., & Saage, K. (2018). Science teachers' perceptions of the emergence of Responsible Research and Innovation in school. *Journal of Baltic Science Education, 17*(4), 590−604.
- Bardone, E., Burget, M., Saage, K, & Taaler, M. (2017). Making sense of RRI in science education through inquiry-based learning. Examples from the field. *Science Education International, 28*(4), 293–304.
- Burget, M., Bardone, E., & Pedaste, M. (2017). Definitions and conceptual dimensions of responsible research and innovation: a literature review. *Science and Engineering Ethics, 23*(1), 1–19. https//doi.org/10.1007/s11948-016-9782-1
- Burget, M., Bardone, E., & Pedaste, M. (2016). Dimensions of Responsible Research and Innovation. In L. Gómez Chova, A. López Martínez, I. Candel Torres (Eds.), *Proceedings of INTED2016 Conference: 10th annual International Technology, Education and Development Conference (INTED 2016)* (pp. 1008−1013). Valencia, Spain: IATED Academy.
- Pedaste, M., De Vries, B., Burget, M., Bardone, E., Brikker, M., Jaakkola, T., Veermans, K., Siiman, L., Mäeots, M., & Lind, M. (2015). Ark of Inquiry: Responsible Research and Innovation through Computer-based Inquiry Learning. In T. Kojiri, T. Supnithi, Y. Wang, Y.-T. Wu, H. Ogata; W. Chen, S. C. Kong, F. Oiu (Eds.). *Workshop Proceedings of the 23rd International Conference on Computers in Education ICCE 2015* (pp. 187−192). Hangzhou, China: Asia-Pacific Society for Computers in Education.
- Burget, M., Pedaste, M., Ugur, K., Lõhmus, E. (2014). How can videos help achieve educational objectives? In *Proceedings of EDULEARN 2014 Conference: 6th annual International Conference on Education and New Learning Technologies (EDULEARN14)* (pp. 1091−1096). Barcelona, Spain: IATED Academy.

ELULOOKIRJELDUS

Nimi: Mirjam Burget
Aadress: Haridustehnoloogia keskus, Haridusteaduste instituut, Tartu Ülikool, Salme 1a, 50103 Tartu
Telefone: +372 5343 2408
E-posti aadress: mirjam.burget@ut.ee

Haridus:

2014–…	Tartu Ülikool, Haridusteaduste instituut, haridusteaduste doktoriõpe
2009–2011	Tartu Ülikool, Loodus- ja tehnoloogiateaduskond, magistrikraad (MA), bioloogiaõpetaja
2005–2006	Leibniz University Hannover, vahetusüliõpilane (Erasmuse programm)
2001–2006	Eesti Maaülikool, Metsandus- ja maaehitusinstituut, bakalaureusekraad (BA), loodusvarade kasutamine ja kaitse
1999–2001	Pärnumaa Kutsehariduskeskus, sotsiaalhooldus
1996–1999	Pärnu Raeküla Gümnaasium

Teenistuskäik:

2018–…	Tartu Ülikool, Haridusteaduste instituut, haridustehnoloogia nooremteadur
2013–2017	Tartu Ülikool, Haridusteaduste instituut, haridustehnoloogia spetsialist
2013	Tartu Ülikool, Loodus- ja tehnoloogiateaduskond, spetsialist teavitustöö alal
2013–2014	Tartu Keskkonnahariduse Keskus SA, keskkonnameedia õpetaja
2009–2014	Tartu Keskkonnahariduse Keskus SA, projektijuht
2008–2014	Tartu Keskkonnahariduse Keskus SA, keskkonnainfo spetsialist
2006–2007	ERKAS Pärnu Instituut OÜ, maastikuplaneerija

Teadusvaldkond: Vastutustundlik teadus ja innovatsioon (RRI) hariduses

Publikatsioonid: vt lk 171

DISSERTATIONES PEDAGOGICAE UNIVERSITATIS TARTUENSIS

1. **Карлеп, Карл.** Обоснование содержания и методики обучения родному языку во вспомогательной школе. Tartu, 1993.
2. **Ots, Loone.** Mitmekultuurilise hariduse õppekomplekt eesti kirjanduse näitel. Tartu, 1999.
3. **Hiie Asser.** Varajane osaline ja täielik keeleimmersioon Eesti muukeelse hariduse mudelitena. Tartu, 2003.
4. **Piret Luik.** Õpitarkvara efektiivsed karakteristikud elektrooniliste õpikute ja drillprogrammide korral. Tartu, 2004.
5. **Merike Kull.** Perceived general and mental health, their socio-economic correlates and relationships with physical activity in fertility-aged women in Estonia. Tartu, 2006.
6. **Merle Taimalu.** Children's fears and coping strategies: a comparative perspective. Tartu, 2007.
7. **Anita Kärner.** Supervision and research training within the professional research community: Seeking new challenges of doctoral education in Estonia. Tartu, 2009.
8. **Marika Padrik.** Word-formation skill in Estonian children with specific language impairment. Tartu, 2010.
9. **Krista Uibu.** Teachers' roles, instructional approaches and teaching practices in the social-cultural context. Tartu, 2010.
10. **Anu Palu.** Algklassiõpilaste matemaatikaalased teadmised, nende areng ja sellega seonduvad tegurid. Tartu, 2010.
11. **Mairi Männamaa.** Word guessing test as a measure of verbal ability. Use of the test in different contexts and groups. Tartu, 2010.
12. **Piret Soodla.** Picture-Elicited Narratives of Estonian Children at the Kindergarten-School Transition as a Measure of Language Competence. Tartu, 2011.
13. **Heiki Krips.** Õpetajate suhtlemiskompetentsus ja suhtlemisoskused. Tartu, 2011.
14. **Pille Häidkind.** Tests for assessing the child's school readiness and general development. Trial of the tests on the samples of pre-school children and first-grade students in Estonia. Tartu, 2011.
15. **Karmen Trasberg.** Keskkooli- ja gümnaasiumiõpetajate ettevalmistus Eesti Vabariigis (1918–1940) õpetajakoolituse ajaloolise kujunemise kontekstis. Tartu, 2011, 207 lk.
16. **Marvi Remmik.** Novice University Teachers' professional development and learning as a teacher: Opportunities and Conditions at Estonian Higher Education Institutions. Tartu, 2013, 129 p.
17. **Pilve Kängsepp.** Küsimuste kasutamine kui võimalus toetada õpilaste arusaamist loetust. Tartu, 2014, 125 p.

18. **Marge Täks.** Engineering students' experiences of entrepreneurship education. A qualitative approach. Tartu, 2015, 150 p.
19. **Reelika Suviste.** Students' mathematics knowledge and skills, and its relations with teachers' teaching and classroom management practices: Comparison between Estonian- and Russian-language schools. Tartu, 2015, 147 p.
20. **Liina Lepp.** The objectives of doctoral studies and factors influencing doctoral study process from the perspectives of different parties. Tartu, 2015, 271 p.
21. **Ülle Säälik.** Reading literacy performance: Metacognitive learning strategies matter, schools have effect on student outcomes. Tartu, 2016, 119 p.
22. **Katrin Saks.** Supporting Students' Self-Regulation and Language Learning Strategies in the Blended Course of Professional English. Tartu, 2016, 216 p.
23. **Anne Okas.** Novice and experienced teachers' practical knowledge in planning, delivery and reflection phases of teaching. Tartu, 2016, 172 p.
24. **Külli Kori.** The Role of Academic, Social and Professional Integration in Predicting Student Retention in Higher Education Information Technology Studies. Tartu, 2017, 168 p.
25. **Ingrid Koni.** The perception of issues related to instructional planning among novice and experienced teachers. Tartu, 2017, 142 p.
26. **Ivar Männamaa.** Development of an educational simulation game and evaluation of its impact on acculturation attitudes. Tartu, 2017, 154 p.
27. **Egle Säre.** Developing the reasoning skills of pre-schoolers through Philosophy for Children. Tartu, 2018, 131 p.
28. **Anu Sööt.** The procedure of guided core reflection for supporting the professional development of novice dance teachers. Tartu, 2018, 135 p.
29. **Tiina Anspal.** The development of teacher identity through role and self-conception in pre-service teacher education. Tartu, 2018, 157 p.
30. **Age Salo.** The dual role of teachers: school-based teacher educators' beliefs about teaching and understandings of supervising. Tartu, 2019, 156 p.