Academia as a Key Factor in Fostering Responsible Research and Innovation with and for Society: The Case of the RRI Hub at RWTH Aachen University

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Abstract Nowadays, society faces challenges like climate change and inequality that are addressed by the Sustainable Development Goals. Academia plays a central role as a driver for innovation through research, teaching, and transfer to develop answers to these challenges. Responsible Research and Innovation (RRI) provides a framework for aligning research and innovation with societal needs. The technical university RWTH Aachen University considers RRI to be one of its main principles and established the RRI Hub as part of its excellence strategy in 2019. The RRI Hub is supposed to strengthen RRI in research, teaching, and transfer, with a focus on sustainable and responsible development, social innovation, and sustainable and inclusive artificial intelligence. This article describes the importance of academia to foster RRI and to structurally integrate it into universities using the example of the RRI Hub at the technical university RWTH Aachen. As a case, a participatory research project in the area of RRI is presented additionally.

Keywords Higher education · RRI · Sustainability · Transformation · Technical university

1 Introduction

In light of the interconnectedness of various societal challenges such as the COVID-19 pandemic or climate change, the United Nations 17 Sustainable Development Goals (SDGs) (United Nations 2015) show that sustainable solutions require the collaboration of different stakeholders and disciplines (Annan-Diab and Molinari 2017; Miller et al. 2014). Thus, a framework for addressing these challenges has been introduced by Responsible Research and Innovation (RRI), calling for socially responsible solutions to consider the needs of all societal stakeholders.

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In the European Union, Responsible Research and Innovation has gained increasing attention as a cross-cutting issue within Horizon 2020 (Owen et al. 2021). In short, RRI aims to align research and innovation with societal needs (Schomberg 2013) and envisions the collaboration of civil society, business and industry, policymakers, the research community, and the education community to find solutions for global challenges. As part of the research and education community, Higher Education Institutions (HEIs) can be important actors in promoting RRI (Margherita and Bernd 2018; Tassone et al. 2018). HEIs can contribute significantly to finding solutions to global challenges through the socially responsible orientation of research, teaching, and transfer (Owens 2017). In particular, universities of technology have the responsibility of educating future engineers, as they are the ones to develop technical innovations (Crawley et al. 2014). Nevertheless, to achieve collaboration of different stakeholders in research and innovation, universities need to open up and conduct research with and for society (Tassone et al. 2018; Ritzen 2020). Thus, universities need to address RRI at different levels. However, prior studies show a lack of research on implementing RRI in higher education institutions (Tassone et al. 2018).

RWTH Aachen University in Germany, one of Europe's leading technical universities, has already created structures to strengthen RRI at the university level (RWTH 2019). With the establishment of the RRI Hub in 2019, a structure for pursuing responsible research and innovation on the three tasks research, teaching, and transfer, was established. The RRI Hub sees the assumption of social responsibility as the objective and the foundation of an excellent university and envisions becoming a nucleus for the socially responsible orientation of the university. Therefore, the RRI Hub conducts several activities interlinking research, teaching, and transfer and to strengthen cooperation of research and innovation within industry, society, government, and academia. We present the goals and activities of the RRI Hub in this article. Further, we present the results of a research-based teaching project, highlighting the relevance of the integration of RRI in research, teaching, and transfer and underlining the statement that interconnecting these three tasks can contribute to a successful implementation of RRI at universities.

Thus, this paper contributes to closing the research gap on implementing RRI in HEIs by pursuing the research question "What role do universities have in implementing RRI with and for society, and how can they succeed?". In section two, RRI will be defined, and the role of RRI in an institution of Higher Education will be explained, taking the specific case of a technical university. Here the current status of RRI at RWTH Aachen University will be deployed. Subsequently, section three presents the RRI Hub in detail by addressing its research, teaching, and transfer activities that aim to promote RRI systematically to serve as an example of how RRI can be implemented in universities. In section four, study results indicate the importance of RRI in technical HEIs and show that applying RRI to all three tasks, which the RRI Hub is implementing and has implemented so far, can be seen as a promising approach.

2 Responsible Research and Innovation

Within the 8th European Framework Program Horizon 2020, Responsible Research and Innovation gained increasing attention as a cross-cutting concept. RRI is a political concept that fosters "(ethical) acceptability, sustainability and societal desirability" (Schomberg 2013, p. 63) of research and innovation by putting society at the center of today's research processes and by aligning research and innovation more closely with society's values, needs, and expectations (Owen et al. 2012). Thus, research and innovation shall be sustainable and morally defensible, and societal interests should be involved in science and innovation to distribute responsibilities equitably among all.

2.1 Definition

The idea of RRI dates back to the early twentieth century and a discussion about the responsibility of science and technology (Owen et al. 2012), leading to an increasing need to link innovation and responsibility (Genus and Iskandarova 2018; Ribeiro et al. 2017). The European Commission has primarily shaped the recognition of the concept of RRI within the European Union during the last decade, with RRI then being a cross-cutting theme within Horizon 2020, the major funding program by the European Union (Owen et al. 2012; Geoghegan-Quinn 2014). Anticipating the impact of research and innovation on society and highlighting the importance of research and innovation in solving global challenges (Owen et al. 2012), the goals of Horizon 2020 include, for example, that actors such as scientists, citizens or organizations work together on research and innovation that fulfill the values and needs of society as a whole in the process and the subsequent result.

Even though different accounts have subsequently approached a formal characterization of RRI (Geoghegan-Quinn 2014; Stilgoe et al. 2013; Jeroen van den Hoven 2013), the most often used definition of RRI (Ribeiro et al. 2017) by von Schomberg (2013) states that RRI…

> "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)" (Schomberg 2013, p. 63).

The definition emphasizes the role of and in service of society and highlights the need for collaboration among business and industry, the education community, the research community, policymakers, and engaged citizens (Owen et al. 2012) (see Fig. 1) to achieve alignment of research with society's needs, as well as to find collaborative solutions to societal challenges and create societal benefit (Schomberg 2013; Tassone et al. 2018; European Commission n.d.).

In an attempt to unify discourses, the EU-funded project 'RRI Tools' (RRI Tools 2016) defined four process dimensions of RRI as a framework for the constant

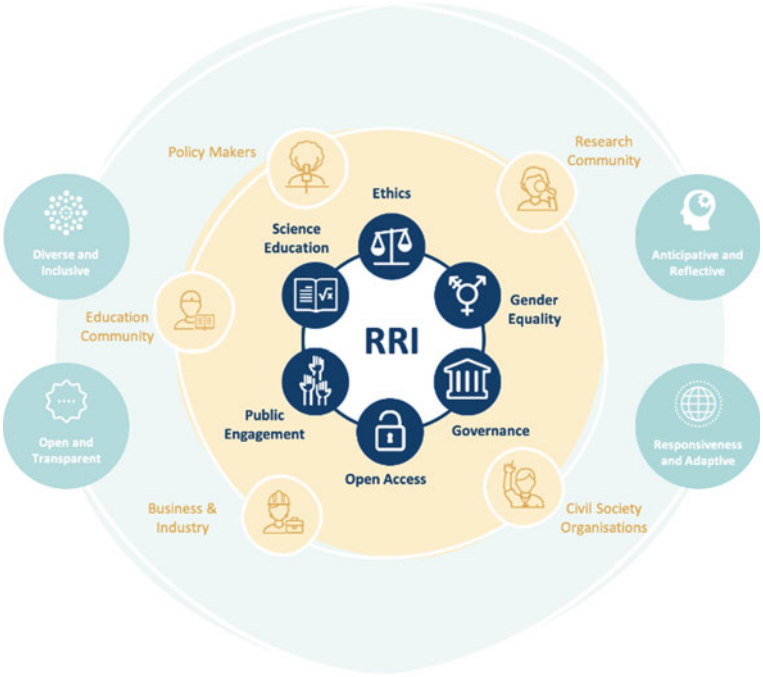

Fig. 1 RRI concept based on RRI Tools (RRI Tools 2016)

exchange between society, politics, the education and research sector, and industry and business (see Fig. 1): diverse and inclusive, open and transparent, anticipative and reflexive, and responsive and adaptive. Diverse and inclusive refers to the diverse involvement of a broad spectrum of actors in research and innovation. This integration of everyone in the respective processes is intended to strengthen the democracy of society and make knowledge more usable. Under the claim to be open and transparent, findings of methods, results, conclusions, and impacts should be communicated openly and transparently. The third point is to look at research and innovation in an anticipative and reflective way to foresee essential insights into possible consequences and thus be more able to act in case of doubt. The last process dimension, responsive and adaptive (in the face of change), sets the goal of being able to adapt research processes and the required structural conditions to changing conditions, needs, or new scientific findings.

In 2014, the European Commission further highlighted six dimensions of RRI: engagement, science education, ethics, gender, open access, and governance (Italian Presidency of the Council of the European Union 2014). However, later, governance was no longer considered a key dimension as it was considered too challenging to implement in the work program and, moreover, it should be considered an underlying dimension of the other aspects (Owen 2013). Therefore, the European Commission addresses the five dimensions within the Science and Society work program (Owen

et al. 2021). The first is to focus on research integrity/ethics and the acceptance of scientific and technological developments in science and society (RRI Tools 2016). The second dimension, gender equality, means that equal gender participation in teams and decision-making bodies should be promoted, and gender dimensions in research and innovation should be taken into account to improve the quality and social relevance of the results (RRI Tools 2016). The third point, open access, is about making scientific information accessible to all. This means making scientific work freely and directly available to improve and accelerate scientific research. In addition, this should facilitate cooperation between individual actors and promote a productive exchange with civil society (RRI Tools 2016). Fourth, public engagement aims to increase society's involvement in research and innovation processes, which are collaborative and depend on the cooperation of a wide range of actors. The intention is to involve all stakeholders throughout the processes and always align with all interests (RRI Tools 2016). The fifth point, science education, focuses on improving current educational processes, empowering citizens to participate in research and innovation debates, fostering new scientific talent, and increasing the overall number of researchers (RRI Tools 2016).

2.2 Responsible Research and Innovation at HEIs

As part of the education and research community, HEIs are supposed to be important stakeholders in RRI (Margherita and Bernd 2018). Education for and with society is a central principle of RRI regarding teaching at HEIs (Tassone et al. 2018). HEIs can address 'education for society' by addressing societal challenges in teaching using appropriate pedagogical concepts where students are active learners (Margherita and Bernd 2018; Tassone et al. 2018). 'Education with society' means integrating different actors in teaching and learning processes. Universities should offer interdisciplinary and transdisciplinary teaching formats by creating opportunities for exchange between students and scientists, government, civil society, or businesses (Tassone et al. 2018). Furthermore, HEIs can foster RRI in research and teaching processes, e.g., by offering inquiry-based teaching formats. By doing so, RRI helps in interweaving research and teaching activities. In research, RRI calls for integrating external stakeholders, like societal actors, in research starting from the beginning of a research process, and considering them as equal research partners (Levikov et al. 2020).

The policy level has already recognized the role of higher education in promoting RRI and has established funding mechanisms for integrating RRI in HEIs, e.g., on EU level through Horizon 2020. The likelihood of RRI being implemented within organizations increases when they actively participate in Horizon 2020 programs (Ryan et al. 2021). Besides, Ryan et al. (2021) show that HEIs are more likely to address RRI if they are characterized by a high level of research intensity and multidisciplinary orientation. However, few HEIs have addressed RRI in their policy frameworks (Tassone et al. 2018) and previous studies show a research gap on how

RRI can strategically be implemented in HEIs (Tassone et al. 2018). Tassone et al. (2017) state that "[f]ostering RRI in higher education curricula is about equipping learners to care for the future by means of responsive stewardship of research and innovation practices that address the grand challenges of our time in a collaborative, ethical and sustainable way." (Tassone et al. 2018, p. 343).

Technical universities could have an essential role in promoting RRI. Including RRI in STEM education trains responsible innovators who, in turn, take RRI into account in later research and development processes. However, to the best of our knowledge, no studies or articles consider the particular role of technical universities in promoting RRI. Therefore, this article also demonstrates how technical universities, using RWTH Aachen University as an example, can successfully implement RRI in research, teaching, and transfer.

We argue that RRI should be implemented holistically in all institutional structures. At the institutional level, RRI should be addressed as a framework. Furthermore, as proposed by the concept of RRI, universities should consider RRI in all three tasks, research, teaching, and transfer, as cross-cutting concept. Following Ribeiro et al. (2017), multiple actors like civil society, industry, and researchers from different disciplines must all contribute to responsible research and innovation. Based on this, HEIs must open up to societal demands and stakeholders to foster RRI.

3 The Responsible Research and Innovation (RRI) Hub at RWTH Aachen University

In the following sections, we show how RWTH Aachen University addresses RRI in research, teaching, and transfer, exemplified by the Responsible Research and Innovation Hub.

3.1 Implementing RRI at RWTH Aachen University—The RRI Hub

RWTH Aachen University started actively assuming the role of initiator and structure provider for socially responsible and sustainable innovation by integrating RRI into its Excellence Strategy in 2019. As part of the Excellence Strategy of the German Federal and State Governments, RWTH was successfully named one of Germany's Universities of Excellence in 2019. Under the heading 'The Integrated Interdisciplinary University of Science and Technology. Knowledge. Impact. Networks.' (RWTH Aachen University 2019), RWTH Aachen University strives to become one of the central national players in the science system that provides sustainable solutions for current and future global challenges. RWTH's vision is "to further grow beyond a unique integrated, interdisciplinary university by embracing the convergence of

knowledge, approaches and insights from the humanities, economics, engineering, natural and life sciences, i.e. biology and medicine" (RWTH Aachen University 2019, p. 1).

Within the Excellence Strategy, RRI is explicitly addressed and called for as "one of the guiding principles" (RWTH Aachen University 2019, p. 47). This integrative approach served as the basis for developing the RRI Hub.[1] As part of the Excellence Strategy's measure 5, 'Collaborate in Living Labs', the RRI Hub was installed with the goal of "foster[ing] the cooperation between science and civil society in order to find meaningful solutions to complex challenges" (RWTH Aachen University 2019, p. 47). The RRI Hub aims to anchor responsible research and innovation as one of the central guiding ideas in research, teaching, and transfer, and become a nucleus for a socially responsible orientation of the university.

The RRI Hub sees the assumption of social responsibility as the objective and the foundation of an excellent university. It is guided by the image of an integrated and interdisciplinary university that is responsible for developing technical solutions to global challenges in its research programs and, at the same time, training future experts (students) who contribute to the sustainable implementation of these solutions in different areas like civil society or business and industry. The RRI Hub aims to strengthen cooperation in research and innovation within industry, society, government, and academia (as part of the research and education community in the RRI concept), following the idea of the quadruple helix (Carayannis and Campbell 2012, 2009; Afonso et al. 2012).

3.2 The Conceptual Framework and Ecosystem of the RRI Hub

The RRI Hub's vision is to become a nucleus for a socially responsible orientation within the three guiding tasks of universities: research, teaching, and transfer (see Fig. 2). The overall mission of the RRI Hub is to foster sustainable and socially responsible research and innovation that meets societal needs. Therefore, the RRI Hub pursues two goals: (1) to foster cooperation between science and civil society to find meaningful solutions to complex challenges in research, teaching, and transfer and (2) to promote and foster the recognition of social commitment through research and transfer. To create opportunities for cooperation, the RRI Hub aims to network, bundle, and concretize competencies through a reciprocal relationship between RWTH Aachen University and other actors, such as civil society. In particular, the RRI Hub focuses on educating students to be responsible innovators of tomorrow to find solutions for global challenges as they are addressed by the 17 SDGs within its teaching activities. To achieve its goals, the RRI Hub incorporates inter- and transdisciplinary perspectives by integrating different disciplines and actors in its teaching and research activities.

[1] www.hub.rwth-aachen.de.

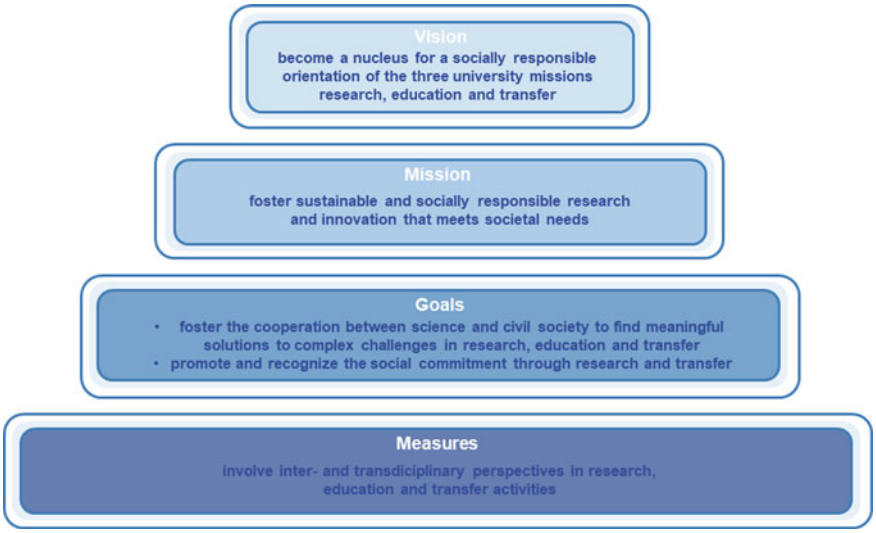

Fig. 2 Vision, mission, goals, and measures of the RRI Hub

All of the activities of the RRI Hub are framed by the Sustainable Development Goals. As an academic actor, the RRI Hub operates in research, teaching, and transfer with different actors of the quadruple helix (Afonso et al. 2012) and has already established successful collaborations based on a community-building approach characterized by reciprocity, interaction, and mutual respect (Berg et al. 2020). In **society**, the RRI Hub works together with, for example, Nongovernmental Organizations (NGOs) to promote civic engagement. Furthermore, the RRI Hub collaboratively works with other partners from **academia** (e.g., other HEIs in Aachen, Germany and worldwide). Here, joint teaching activities and research projects are conducted on topics related to the 17 SDGs. Further, collaboration with **governmental actors**, like the municipality of Aachen, is part of the transfer activities of the RRI Hub, aiming to sensitize for RRI and strengthening joint activities between academia and other actors. Lastly, collaborations with **industry** are, for example, established within teaching such that industry partners are invited to give talks in courses and seminars.

3.3 The Focus Areas of the RRI Hub

The RRI Hub's activities within research, teaching, and transfer are located within three focus areas (see Fig. 3). The focus area of sustainability and responsible development forms the overarching thematic focus of the RRI Hub. All activities aim to promote a socially responsible and sustainable orientation of research, innovation, and education. Based on this, the focus areas social innovation and social entrepreneurship, and sustainable and inclusive artificial intelligence are derived.

Promoting social innovation and social entrepreneurship is one practical way HEIs can actively implement and support RRI and contribute to achieving the SDGs. Furthermore, despite the demand at the EU level, social innovations are not yet systematically promoted at universities (Cinar and Benneworth 2021). Artificial intelligence as general purpose technology (Cockburn et al. 2018) has become a driver for innovation and technological change (Littman et al. 2022) in various application fields with highly influential power and therefore radiates into many disciplinary domains. Besides, AI is known to equally transform science and society (Harari 2017).

Sustainability and Responsible Development

As the overarching thematic focus, all of the RRI Hub's activities are aligned with the SDGs and have sustainability and responsible development as their starting point and main focus. For example, various SDGs are addressed in all courses and seminars offered with the aim of addressing a holistic understanding of sustainability, demonstrating the importance of all dimensions, and enabling students to act responsibly. Furthermore, all of the RRI Hub's research activities aim to contribute to the achievement of a sustainable and responsible future. Science with and for society,

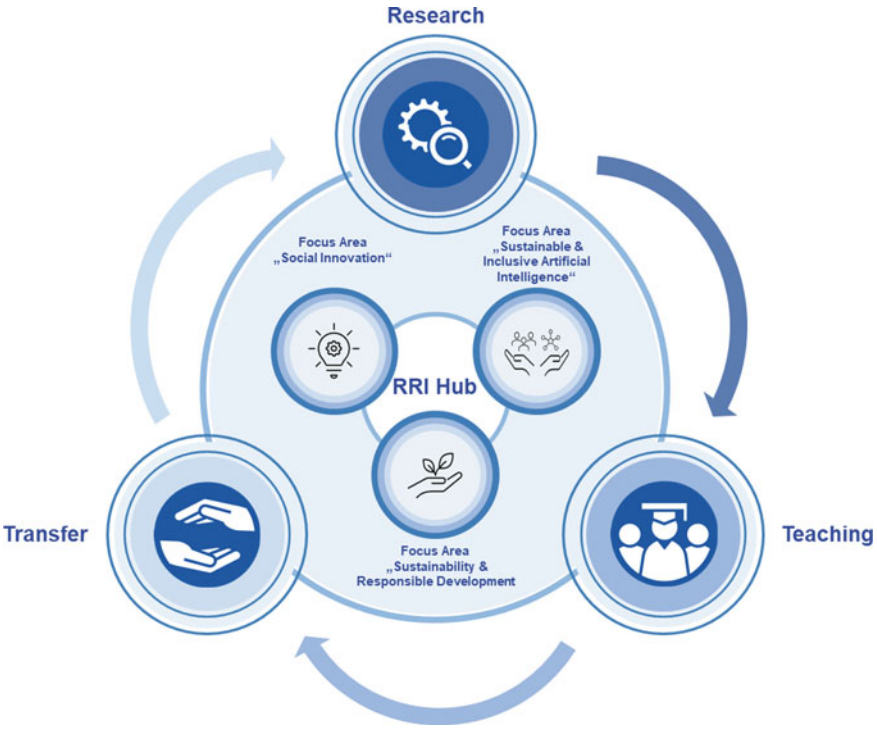

Fig. 3 Relational diagram of the activities of the RRI Hub

as addressed in the RRI concept, forms the conceptual framework of the RRI Hub's research activities.

Social Innovation

Current global challenges, as they are, for example, addressed by the 17 SDGs, show that innovative solutions are needed that go beyond technical innovations (Bayuo et al. 2020). The importance of social innovation and social entrepreneurship in addressing global challenges has been increasingly discussed in the literature in recent years (Cinar and Benneworth 2021; Bayuo et al. 2020; Benneworth and Cunha 2015; Cinar 2019; Cunha and Benneworth 2020; Kumari et al. 2020). Connected to RRI, social innovations are often characterized by collaboration between different actors so that, in the sense of the quadruple helix, industry, civil society, government, and academia are all involved in the innovation process. In particular, the role of academia and universities has been increasingly discussed in recent years (Bayuo et al. 2020). Within its report 'A European Ecosystem for Social Innovation', the European Commission highlights universities' role as a driver for social change by promoting social innovation and states that universities and social organizations should create opportunities for dialogue between different stakeholders (European Commission, Directorate-General for Research and Innovation, Georghiou L 2018). By promoting RRI, HEIs could highlight the need for collaboration between science and society or government, which could foster HEIs' role in social innovation. However, studies show that universities have not yet established supporting conditions for social innovation and social entrepreneurship on all university levels (Bayuo et al. 2020). Besides, there is still a lack of research on the role of universities, particularly technical universities, in social innovation processes (Cinar and Benneworth 2021; Bayuo et al. 2020; Berg and Leicht-Scholten 2021). With a growing interest and relevance of social-tech entrepreneurship (Calderini et al. 2021), technical universities can contribute to finding solutions to global challenges by promoting and connecting social innovation and technical innovation.

Based on the intersection of social innovation and RRI, the RRI Hub works on topics such as social innovation and social entrepreneurship in research, teaching, and transfer. In particular, the RRI Hub explores the role of technical universities in fostering social innovation and social entrepreneurship. The RRI Hub's research also addresses the extent to which students at technical universities already understand social innovation and the extent to which they can envisage a professional future as founders or employees in a social enterprise. The aim is to close the research gap on the role of universities in social innovation and to derive recommendations for action for technical universities.

Sustainable and Inclusive Artificial Intelligence

Current developments show that digitalization and AI reach a diverse field of application areas with highly influential power. Digitalization and AI have become drivers for transformation and technological change and will have a long-term influence on society and communities (Littman et al. 2022), productivity, equality, and the environment (Vinuesa et al. 2020). Consequentially, AI impacts sustainability as defined

by the UN SDGs in its many dimensions. For example, AI may help to reach the basic provisions of clean potable water, green energy, and food security (Mondejar et al. 2021).

Yet, it is not a straightforward task to analyze the transformative outcomes of digitalization and AI with regard to its positive or negative impacts. While AI may have a negative impact on 59 targets of the SDGs, more than three-quarters (134 targets) may benefit from the use of AI (Vinuesa et al. 2020). By focusing on sustainability's economic pillar, AI is estimated to add around 14% to the global economy by 2030 (Mondejar et al. 2021). However, using AI will also lead to significant changes in the work environment and introduce new risks for the labor market (Rajnai and Kocsis 2017). In the pillar environment, it is important to recognize the ongoing discourse between AI for sustainability and the sustainability of AI. The latter is less often addressed in current research, although the technology itself has huge environmental costs (Vinuesa et al. 2020; Wynsberghe 2021). To gain a meaningful overview, the whole socio-technical system needs to be considered (Wynsberghe 2021). The positive impact of AI on the (societal) infrastructure, such as transportation, energy, and education will also create new dependencies and must be addressed in the early stages of integration and development (Robbins and Wynsberghe 2022). Perhaps the most difficult influences to predict and relate to the third pillar of sustainability: society. Taking the World Wide Web as an example, we see that digitalization has the potential to distribute access to knowledge, information, and skills, and may also be an enabler for political participation. However, in many countries, the web lacks clear practices to protect privacy or act against discrimination, and it is currently controlled by large companies and states with the possibility to limit freedom of speech. Furthermore, many poor areas still do not have any access—thus, the web may even increase inequalities (Foundation 2015). Moreover, the discussed transformations exhibit a clear deficit with regard to SDG 5 'Gender Equality' (Vinuesa et al. 2020). A digital gender gap can be observed online (Initative D21 e.V. 2020), and beyond, examples of discriminatory AI with respect to gender or race accumulate [e.g. (Barocas et al. 2017)]. Meanwhile, more and more initiatives address AI for social good (Cowls et al. 2021) as AI has become an important means to identify problems (e.g., poor areas (Jean et al. 2016); discrimination (Heinrichs 2021)) and thus can generate actionable knowledge.

This actionable knowledge may bridge gaps between society, technology, and academia and may enhance adequate strategies for governance. In particular, as a cross-cutting topic, a fair, sustainable, and inclusive use of AI radiates into all other focus areas. Looking ahead to the field of social innovations and entrepreneurship, AI-applications are seen as both: a general purpose technology which can be used for various applications in various fields (Cockburn et al. 2018), but also as an invention as a method of invention (Cockburn et al. 2018), so it can, for example, be used to address urgent environmental challenges with novel methods (George et al. 2021). It is a straightforward conclusion that RRI initiatives must address the impacts of AI and digitalization. Taking AI and digitalization as the focus of RRI will help to analyze and address societal impacts from a long-term perspective. Therefore, the RRI Hub

conducts research on how to integrate sustainability and diversity perspectives in AI systems for ethical and responsible use.

3.4 Research—Teaching—Transfer: The Three Tasks Addressed by the RRI Hub

An overall goal of the Excellence Strategy (RWTH Aachen University 2019) is to "create a unique education, research, and transfer hub with dynamic research networks crossing disciplinary and organizational borders" (RWTH Aachen University 2019, p. 1). The RRI Hub therefore fosters engagement across the three tasks: research, teaching, and transfer. In line with RWTH's Excellence Strategy, transfer is "the continuous and mutual exchange of ideas, knowledge, technologies and people within RWTH, with partner organizations, societal groups and industry." (RWTH Aachen University 2019, p. 20). This means to drive collaboration between academia and society as well as industry and government. However, to have a holistic effect in all university areas, the combination of the three tasks is essential.

Research

The Excellence Strategy formulated the research mission of the RRI Hub as follows: "An essential component of the RRI Hub is to integrate students in interdisciplinary research teams working on solutions to real problems with non-profit organizations" (RWTH Aachen University 2019, p. 47). Therefore, the RRI Hub conducts research in RRI and integrates students' and societal perspectives through a responsible and sustainable design of research and development processes. The goal of the RRI Hub's research is a better alignment of scientific results and societal needs through open participation. Integration of citizens in research processes ranges from a passive consumption of science to a high engagement, for example, in data collection and analysis (see ladder of participation, Arnstein 1969). The RRI Hub conducts research projects using methods such as citizen science and living labs. Living labs are to be understood here as temporally and spatially limited test spaces where innovative technologies and models can be tested under real-life conditions as an appropriate, concrete way to involve citizens in the design and experimentation of new innovations (Wagner and Grunwald 2015).

Examples of Research Activities

One example of research activities of the RRI Hub is the Living Lab Templergraben (Templergraben 2023), a collaborative project with partners from different sectors, for example, the student initiative Uni.Urban.Mobil, the NGOs VCD and ADFC, the city of Aachen, and the AStA (student representation) of the RWTH Aachen University. The goal was to evaluate mobility concepts by closing a particular road in the main campus area to individual motorized traffic and, at the same time, evaluate the use of the resulting newly created spaces. The RRI Hub supported this project

and, in particular, conducted quantitative research, evaluating the acceptance and success of the project.

Furthermore, international cooperation can enhance the quality and impact of research. Currently, two projects are planned with international partners on the focus topics of 'social innovation' and 'sustainable and inclusive artificial intelligence'. Thus, the RRI Hub works on research projects together with other European universities. In the field of social innovation and social entrepreneurship, the RRI Hub conducts research with partners of the ENHANCE Alliance. Through a survey among students at the ENHANCE universities, the research project aims to examine how social entrepreneurial structures impact STEM students' social entrepreneurial intention. The study will also contribute to explaining how perceived social norms could affect STEM students' social entrepreneurial intention. Thus, the results could contribute to discovering how technical universities can strengthen and support social innovation processes. Accordingly, a journal paper on the role of European technical universities in social innovation processes will be published in 2024.

To assess algorithmic bias and unfairness in the context of 'Sustainable and Inclusive Artificial Intelligence' (Decker 2021), research on participatory approaches for fair Explainable AI (XAI) is planned. Giving credit to the fact that perceived fairness of AI heavily depends on several factors, such as the circumstances under which a decision is presented (Grgic-Hlaca et al. 2018), explanations must be understandable and well-interpretable for laypersons who are affected by a decision but do not have any background knowledge on AI (Decker 2022). Therefore, non-experts, and in particular those who are often not involved in decision-making processes, shall be involved in the development of fair and inclusive AI.

Education and Teaching

As a university with a focus on the technical sciences, RWTH Aachen University sees itself not only with the responsibility to develop technical solutions for global challenges but also to train excellent experts who will contribute to the development of solutions and their implementation in science, industry, and society (Leicht-Scholten and Krieg 2019). As future decision-makers, students have a decisive multiplier role in implementing sustainable development as described by the Sustainable Development Goals (United Nations 2017). This means a mutual exchange of ideas, knowledge, technology, and people within the university, with partner organizations as well as with business and society. Active learning approaches, such as problem-based, project-oriented, and case-based learning have been proven to be the most appropriate methods for providing meaningful education for sustainable development (United Nations 2017; Beagon et al. 2022). These approaches empower students to explicitly take action instead of remaining simple 'observers' of the world around them. The RWTH Aachen University has developed its strategy for a competence-oriented, research-led, and practice-related education of highly qualified and responsible graduates where social responsibility forms the foundation for excellent research (Hochschulrektorenkonferenz 2017; RWTH Aachen University 2009; Steuer-Dankert et al. 2019; Leicht-Scholten et al. 2020) and "[e]lements

of social responsibility and sustainability will be gradually integrated in the educational framework of all curricula." (RWTH Aachen University 2019, p. 47). A strong opening of the HEI in the direction of civil society and active participation of the students in social issues can move social commitment specifically into institutional focus. Problem-based learning and project work are a means to strengthen RRI and science education in educational institutions (Hazelkorn et al. 2015).

To train responsible innovators for sustainable development, the RRI Hub offers teaching formats in cooperation with various internal and external university actors. The goal here is to teach students to acknowledge their own social responsibility and to empower them to take action towards achieving the SDGs. The RRI Hub pursues competence-oriented teaching in all basic and advanced modules and offers interdisciplinary and cross-cutting modules to convey intercultural competencies and global perspectives.

Examples of Teaching Activities

Examples of the RRI Hub's teaching activities include interdisciplinary courses within Project Leonardo, a project at RWTH Aachen for interdisciplinary courses on social challenges in which lecturers from different disciplines contribute their expertise. The RRI Hub offers, together with the FH Aachen and the Catholic University of Applied Sciences Aachen, the course 'Sustainability and Transformation as an Opportunity and Challenge for Society'. In this course, the various dimensions of sustainability are considered and discussed. Building on keynote speeches, current problems are worked on in cross-university and cross-disciplinary groups, and proposed solutions are developed. Based on the concept of citizen science, the course invites speakers from all sectors: experts from various scientific fields, (social) start-ups, civil societal actors like NGOs, and governmental actors. This approach allows students to consider sustainability holistically and to learn about it from the perspective of different experts. On the other hand, the experts can explore the students' points of view during the discussions (Hub 2022).

Furthermore, two significant projects will be implemented in 2023. Promoting responsible societal transformation is one goal of the European university alliance 'ENHANCE'. The alliance, consisting of different technical universities in Europe, has been funded by the European Commission since the end of 2020. Within ENHANCE, the RRI Hub has developed the Massive Open Online Course (MOOC) 'Responsible Innovators of Tomorrow' in collaboration with colleagues from other ENHANCE universities. Based on the OECD Learning Compass (OECD 2019), the MOOC covers topics related to responsible innovation, with a focus on science and technology studies. Embedded in this European project, students will not only learn more about topics like RRI and social responsibility but will also get the chance to exchange with international experts (https://enhanceuniversity.eu/about-us/). Furthermore, the RRI Hub integrates project-based learning in different teaching formats, for example, in a seminar on current challenges in the context of RRI and in a Winter School on RRI, which was offered in March 2023.

Transfer

As already mentioned, the RRI Hub pursues the goal of strengthening the transfer to society and the involvement of non-academic stakeholders in research and innovation processes to find solutions for global challenges. To this end, various projects are implemented with regional, national, and international actors. Furthermore, at the university level, the RRI Hub collaborates with diverse actors such as, for example, with the Staff Unit for Sustainability and University Governance (see Höhl et al. 2024), rectors delegates for sustainability in teaching and research, and with the student representation (AStA) of RWTH Aachen University.

Examples of Transfer Activities

The RRI Hub works together with the city of Aachen, the civic foundation Lebensraum Aachen, and the AStA of RWTH Aachen University in a project called 'Engagierte Stadt' ('Engaged City'). In Germany, there are more than 100 cities that have received the 'Engagierte Stadt' label and thus promote civic engagement (Engagierte Stadt 2022). The difference in Aachen, compared to other cities, is the cooperation of different actors from civil society, academia, student body, and government within the framework of the 'Engagierte Stadt'. The aim of the project is to create a democratic, diverse, and solidarity-based society in which engagement is actively lived. Besides, bundling resources, networking and exchange, and making engagement visible are the main goals of the project. For this purpose, among other things, a regular exchange of the actors takes place and joint projects are implemented.

Furthermore, the RRI Hub is a co-initiator of the network 'Social Entrepreneurship Euregio (SEEu)'. SEEu is committed to building an ecosystem for social and sustainable innovation in Aachen and the Meuse–Rhine Euroregion (Social Entrepreneurship Euregio 2022). The network was initiated by Aachen's universities and other organizations from Aachen's business community and civil society. The target groups are students, start-up entrepreneurs, social entrepreneurs, and all those interested in sustainable and social innovation. SEEu organizes events, e.g., on the topic of impact investment and offers networking and exchange of experience to founders, start-ups, and all those interested in social entrepreneurship.

4 How to Practically Interconnect RRI in Research, Teaching, and Transfer?

"When it comes to the connection between research and education, as suggested by Healey (2005 p. 68), students are likely to gain most benefits from research when they are actively engaged in it, through for example inquiry-based processes" (Tassone et al. 2018, p. 342). Based on this assumption, the RRI Hub integrates students in research projects in the context of RRI and thus links research and teaching. The example project presented in this chapter underlines with its results the importance of doing so.

The course 'Engineer meets User' at the Faculty for Civil Engineering at RWTH Aachen University uses a research-based teaching and learning format in which more than 100 engineering students actively engage in research on topics in the context of RRI. The RRI Hub provides a general broad course topic based on current technological developments. The students are first familiarized with social science research methods during the course. They, for example, learn the basics of questionnaire construction for quantitative research. Afterward, the RRI Hub and the students jointly develop a questionnaire which the students distribute. At the end of the semester, the students discuss the results in groups and present their evaluation in a scientific paper, a scientific poster, and a video including recommendations for stakeholders of the quadruple helix. The students are accordingly involved in different phases of the research process. The collaborative work between the RRI Hub and the students ensures that their knowledge and interests are included within the questionnaire and that they can engage with the RRI Hub's topics. By actively being involved and following the research process, the students will be enabled to independently identify research questions, describe and reproduce the main stations in the research process, develop an appropriate research design for the research questions, and apply social science research methods.

The course topic of the summer semester 2022 was 'The Responsible City of the Future – Visions for Aachen'. Based on the transformation of cities due to, for example, climate change or demographic change, the survey aimed to determine to what extent citizens of Aachen, especially students, envision a city of the future and how universities can foster cooperation between different stakeholders such as civil society, industry, academia, and government. To explore the citizen's understanding of responsibility and the importance of participation, items to explore the interlinkages between innovation, artificial intelligence, and responsibility in the urban environment were added. By participating in all stages of the research process, students could identify the current challenges of their city and assess a broader public's view on these topics.

4.1 Methodology

The quantitative online questionnaire co-developed by members of the RRI Hub and the students consisted primarily of closed multiple-choice questions with additional free text fields. The questionnaire was distributed online within four weeks in May and June 2022 without any restrictions. It took the participants 10–12 min to complete the questionnaire, and the framing of the questions addressed students in particular.

In total, over 951 people, mainly residents of Aachen, took part in the survey over four weeks. Of these, 47.5% of participants reported to be female, 46.7% were male, and the remainder were either diverse or did not specify their gender. Most respondents reported being between the ages of 19–22 (41.0%) or 23–26 (39.2%). A total of 3.3% were younger than 19 years, and 12.0% were over 26 years of age. Accordingly, 72.4% of the respondents stated that they were students, 13.9% were

employed, and the rest were pupils, in training, or retired. For the project, a direct connection of the participants to the city of Aachen or its immediate surroundings was useful. 77.2% of the participants had such a connection to the Aachen city region. At just over 62.7%, the vast majority also resided in the surrounding area. Another 14.5% were regularly in the area due to their professional or academic activities.

4.2 Subject

To support students in understanding the importance of involving different stakeholders and perspectives in sustainable transformation and development processes like formulated within the RRI concept, the questionnaire addressed five focus areas: society and participation processes, economy, infrastructure, academia, and individual aspects. During the course, the relevance of the five areas or actors in the context of sustainability and responsible development was discussed with the students. Based on this, the RRI Hub and the students jointly developed survey questions in all five focus areas.

The area of society and participation processes addressed citizens' desire to contribute to Aachen's development. For example, questions were asked about the extent to which citizens take advantage of participation formats such as living labs and would like to get involved in public decision-making processes. In addition, the participants were asked to what extent they would like cooperation formats between science and society. Based on our research question, the aim with this area was to find out specifically how exactly HEIs can engage society in the area of RRI. In the economy part of the survey, the role of local companies in the city of the future was emphasized, and respondents were asked to give their opinion on the influence they attribute to different local stakeholders. The infrastructural questions aimed at the current mobility behavior of Aachen's citizens, their perception of public spaces in this context, and the general cityscape and soft location factors. Questions revolving around the field and role of academia were, for example, intended to provide information about the participants' perceptions of the extent to which they believe they, as citizens of Aachen, can participate in current research projects of the local HEIs. This aimed at exploring the role of technical universities in strengthening RRI. Further, participants were asked how well-informed they feel about current research topics by the RWTH Aachen University and researchers. The two other focus areas of the RRI Hub (sustainable and inclusive AI and social innovation) were also addressed in the questionnaire to explore the connection of these topics to sustainable transformation and development processes, so respondents were asked individual questions on both topics. Individual aspects in the questionnaire included particular questions about the respondents' lifestyle to explore their attitudes to life, e.g., whether a sustainable lifestyle is essential for them or whether respondents are actively involved in climate protection.

4.3 Results and Discussion

In the following, some study results will be exemplarily presented and discussed in the context of RRI. Further, it will be derived which role citizens assign to universities in implementing RRI with and for society.

Society and Participation Processes

The participation of different stakeholders in research and innovation processes is one of the core ideas of RRI (Schomberg 2013). HEIs, in particular, can play an important role here by actively addressing and involving citizens in research and teaching projects. The extent to which this is desired and perceived by citizens was asked in the questionnaire**.** Most of the survey participants generally agreed that citizens should actively engage in research processes (cf. Figure 4a). 65% of the participants agreed or strongly agreed with the statement, "Citizens should be actively involved in research processes at appropriate points". This result supports the call for HEIs to create opportunities for the involvement of citizens in research processes.

One example of fostering participation processes among citizens—one of the key components of the RRI concept—is by using so-called living labs (German 'Real-labore'), a concept that the RRI Hub has addressed, for example, in the Living Lab Templergraben (see above, Sect 3.2). 57% of the participants in the survey saw potential in living labs as they agreed or strongly agreed with the statement, "I positively assess the potential of living labs as an opportunity for citizen participation". However, as 28% answered to that same statement, "I don't know" (and the remainder disagreed or strongly disagreed), it could be assumed that citizens are not familiar with the concept of a living lab. This assumption can be supported by literature as research has suggested that citizens are not always aware of the possibility of contributing to research projects via citizen science (Kam et al. 2021), thus showing the need for the interconnectedness of research, teaching, and transfer.

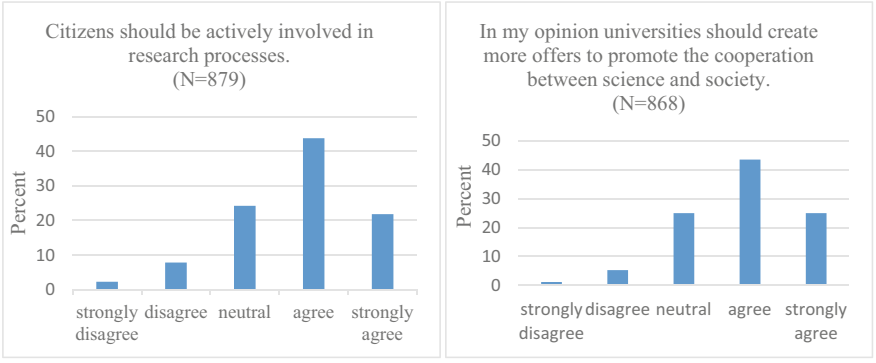

Fig. 4 Results of the statements **a** "Citizens should be actively involved in research processes" and **b** "In my opinion universities should create more offers to promote the cooperation between science and society"

At the same time, participants see universities as having a responsibility to provide more support for this process. 63% agreed or strongly agreed with the statement, "In my opinion, universities should create more offerings to promote collaboration between science and society". (cf. Figure 4b). The results thus show a clear desire among respondents for more collaboration. Collaboration opportunities could range from active involvement in research and innovation processes to discussion events on scientific topics or poetry slams. 'Science for and with society' as a critical principle of RRI (Owen et al. 2012) highlights the need for collaboration opportunities. For the scientific community to conduct 'science for society', the views and interests of societal stakeholders must be understood. This results in the relevance of exchange formats between stakeholders to implement the principle of 'science with and for society' from the university side.

Academia

Academia as an essential stakeholder in RRI processes can contribute to a responsible and sustainable future through, among other things, socially responsible research and education. To address this, issues in the context of RRI can, for example, be discussed in university courses. The questionnaire asked participants to what extent they would like ethical issues, as one dimension of RRI, to be included in their study programs. Participants generally thought ethics is a cross-cutting topic and should be included in all study programs. 57% of the participants agreed or strongly agreed with the statement, "I think ethical issues should be discussed in every study program" (cf. Figure 5).

The questionnaire also addressed the role of innovation and AI for a responsible and sustainable future. Social innovations, in particular, can contribute to achieving the SDGs. The results show that 43% of respondents would support the promotion of such innovations that contribute to the achievement of the SDGs. However, 35% were neutral toward the statement, and 20% disagreed or strongly disagreed. The European Union and individual state governments have recognized the importance of social and sustainable innovation to achieve the SDGs and established special support

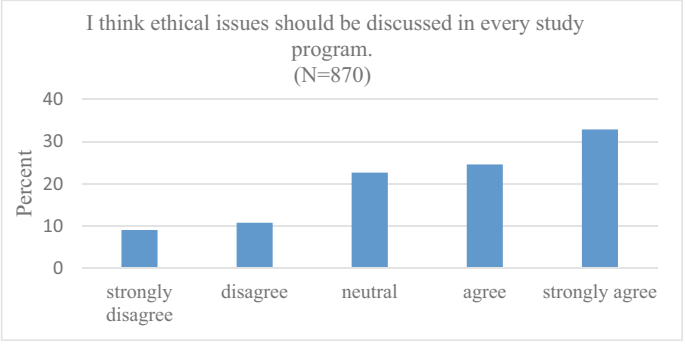

Fig. 5 Results of the statement, "I think ethical issues should be discussed in every study program"

measures like funding for social enterprises (Borzaga et al. 2020). In Germany, the federal government has also set itself the goal of developing a strategy to promote social innovation in the coalition agreement of 2021 (SPD, Bündnis 90, Die Grünen und FDP 2021).

Aachen's citizens were further asked about their opinion regarding several aspects of AI, which, as a cross-cutting topic, is and will be especially relevant in the context of sustainable city development. In light of the rapid growth of AI technologies (Cheung 2022) and its inherent risks (Tsamados et al. 2020), participants were first asked whether they felt positively inclined toward using AI. Ultimately, participants saw a huge potential in AI because 54% agreed or strongly agreed with the statement, "I fundamentally see the use of artificial intelligence as an opportunity for society" (cf. Figure 6a). However, growing in their impact on life-influencing decisions based on predictions and classifications (Hildebrandt and Gutwirth 2008), AI systems show tendencies to reinforce already existing biases (Zhao et al. 2017), produce unfair or discriminatory outcomes, or to systematically reinforce stereotypes and inequalities (Bozdag 2013). Results showed that participants were well-aware of these risks. 36% of the participants agreed or strongly agreed with the statement, "I think the use of artificial intelligence poses significant risks to society" (cf. Fig. 6b). Overall, more people saw AI as an opportunity than as a risk. A Pearson correlation shows that participants of the study, who generally saw the use of AI as an opportunity for society, also thought that its use entailed considerable risks for society ($r = 0.825$, level of significance 0.01, $N = 951$).

Consequently, ethical perspectives must be included in the development and usage of AI to ensure inclusive and sustainable use. This approach has been addressed by many policy papers lately (Hacker 2018; Jobin et al. 2019). This is supported by the survey in which 54% of the participants agreed or strongly agreed to the statement "I think ethical perspectives are paramount in the development and use of artificial intelligence" (30% were neutral toward the statement and 15% disagreed or strongly

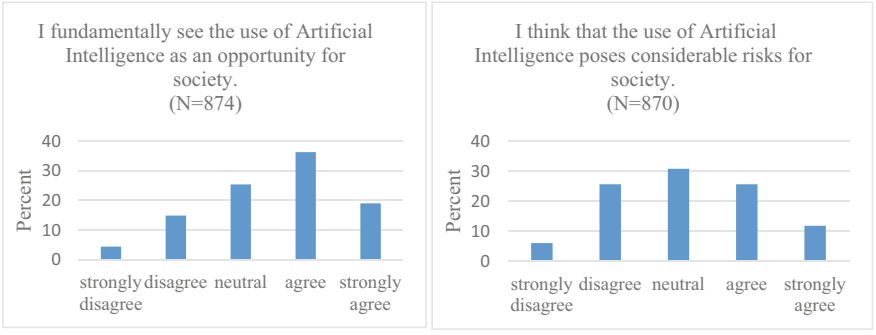

Fig. 6 Results of the statements **a** "I fundamentally see the use of artificial intelligence as an opportunity for society" and **b** "I think that the use of artificial intelligence poses considerable risks for society"

disagreed). This statement supports the RRI Hub's research in the area of sustainable and inclusive AI.

Overall, the survey showed that many respondents, mainly students, considered topics in the context of RRI to be highly relevant. In particular, the survey results indicate that universities are highly responsible for actively involving citizens in research and development processes to foster 'science for society'. Furthermore, regarding transfer to and from society, the results show a need for universities to establish possibilities for collaborations between science and other stakeholders in the context of RRI. This is possible, for example, through implementing projects or events with societal stakeholders, such as those organized by the RRI Hub as part of the 'Engagierte Stadt' project. There are various examples of the successful involvement of different stakeholders in the research process. These examples include citizen science projects or living labs, and the results show that citizens desire participation in research processes. To successfully implement RRI at HEIs, this means creating opportunities for science and society to work together on research projects. In particular, promoting citizen science or living labs can play a role here. In terms of teaching, the necessity of including RRI and knowledge about its process dimensions, such as ethics, in all study programs becomes evident. The relevance of cross-cutting, interdisciplinary topics such as AI must be recognized, and ethical perspectives integrated into all study programs. To summarize, this case highlighted the need for a holistic view of RRI at the university level. The results show that a consideration of RRI in all three tasks—research, teaching, and transfer—is necessary and desired by citizens as well as students. In order to achieve integration of all tasks, the example of the RRI Hub shows that the structural anchoring of RRI at the university level is also essential.

5 Outlook

This article explored the role of universities, especially technical universities, in implementing RRI with and for society and some approaches in succeeding to do so. Using the concrete example of the RRI Hub at RWTH Aachen University, this paper showed how RRI as a framework for aligning research and innovation with societal needs and achieving the SDGs could be anchored at HEIs. This article showed further, how RRI can be addressed in the contexts of research, teaching, and transfer at a technical university. Despite taking into account the facts that the results of the presented study are limited due to the number of participants (approximately 900 citizens of Aachen) and that the results may be biased due to the high percentage of students, the case nevertheless demonstrates the relevance of integrating RRI across all university areas. Nevertheless, the anchoring of topics in the context of RRI in teaching and collaboration opportunities between different stakeholders are desired by citizens and students. It is therefore important to not only remain theoretical, but also to become active within the opportunities that one has as academic actor in research and teaching. The relevance of taking RRI into account at a strategic level is

evident. It further stresses the necessity to consider RRI a strategically important topic to be integrated into research and innovation, as well as into the educational strategies of technical universities and HEIs in general. In line with Margherita and Bernd (2018), we argue that all employees should be sensitized to RRI. Projects like the RRI Hub can be one possibility for HEIs to provide an impetus for responsible research, innovation, and the education of responsible innovators. Strategies for implementing RRI at all levels of universities remain to be explored, and more research must be conducted to develop recommendations on implementing RRI sustainably. Through its activities in the three fields of research, teaching, and transfer, the RRI Hub can address the topic of RRI not only within the university but also outside it.

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