Technology assessment in science and engineering: theory, policy and practice of integration research

Handbook of Technology Assessment

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Handbook of Technology Assessment

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8. Technology assessment in science and engineering: theory, policy and practice of integration research

Mareike Smolka and Erik Fisher

RESURGENCE OF INTEGRATION: THE (IM)POSSIBILITY OF INTEGRATION RESEARCH?

Over the last two decades, we can observe three temporally and geographically distinct but interrelated surges of integration in science and technology policy, funding and practices. In the United States, the 21st Century Nanotechnology Research and Development Act of 2003 was considered as an unprecedented federal requirement for integrating societal considerations into nanotechnology research and development (R&D) (Fisher 2019, p. 1139). Within a decade, calls for socio-technical integration had permeated European Commission research funding programme solicitations (Rodríguez et al. 2013), heralding the emergence of responsible research and innovation (RRI) as a cross-cutting issue. By late 2017, policy emphasis on socio-technical integration had receded in the United States, while increasing talk about 'the end of RRI' (Fisher 2018, p. 253) seemed to suggest that it would also vanish from the European R&D landscape. In recent years, however, integration has resurged in multiple arenas of science and technology.

In 2019, the Organisation for Economic Co-operation and Development (OECD) published a recommendation on responsible innovation in neurotechnology which proposes to 'integrate ethical considerations and take into account public values and concerns at the planning stage and design phase of technology development' (OECD 2019, p. 6). In the same year, integration was featured as a key element of the assessment process in a general model of technology assessment (TA) (Grunwald 2019, p. 137), and the formation of a *Cluster Integrierte Forschung* spanning across institutions in the United States, Switzerland and Germany gave fresh impetus to integration research (Gransche/Manzeschke 2020). In these examples, integration refers to the joining of different actors, ways of producing knowledge and value considerations to render processes of science and technology development more responsive to societal concerns.

Whereas policy solicitations and project managers often seem to assume that such integration is possible, a growing body of literature on the conditions and practices of integration research questions whether it may be an 'impossible project' (Maasen 2021). Social scientists and humanities scholars involved in collaborative projects with natural scientists and engineers point at the practical obstacles to achieving integration across socio-technical divides. Practical obstacles include but are not limited to epistemological and cultural differences, diverging quality standards and power asymmetries (e.g., Viseu 2015). These obstacles can be exacerbated if industry representatives and societal stakeholders join collaborative projects (Braun/Könninger 2017). The knowledge and values of societal stakeholders are sometimes recognised only insofar as they fit the frameworks of academic researchers or the interests of powerful industry actors (ibid.).

In light of both uncritical and critical emphases on integration, this chapter reviews its theory, policy and practice histories. To exemplify how these histories can be interrelated, it turns to socio-technical integration research (STIR) as a practical approach to TA. We situate STIR in the literature and history of integration to clarify its theoretical underpinnings, carve out its specific methodological features and elaborate on its achievements, challenges and perspectives. The chapter complements earlier attempts to 'map the integrative field' (Fisher et al. 2015; Schikowitz/Maasen 2021) by tracing the conceptual diversity and interwoven histories of collaborative research on socio-technical integration. Moreover, STIR serves as a case of integration research to reflect on the (im)possibility of integration more broadly. The chapter concludes by suggesting that pronouncements on the success or failure of socio-technical integration must be considered alongside its role in the broader context of cultural change.

TERMINOLOGY: INTEGRATION, INTEGRATIVE OR INTEGRATED RESEARCH?

Integration derives from the Latin verb *integrare*, which means 'to restore', 'to complement' or 'to make whole' (Schikowitz/Maasen 2021). It is the opposite of segregation, which dissects wholes into parts. In the title of Gransche and Manzeschke's (2020) German-language book on integration research, *Das geteilte Ganze*, the editors engage with the etymological roots of integration in a double sense. On the one hand, the adjective *geteilt* refers to the scientific analytical approach of dissecting *Das Ganze*, that is, the whole; on the other hand, it means 'shared' and indicates the common horizon or goal that motivates scientific activity as a whole. Integration is thus a matter of working across increasingly specialised bodies of knowledge to address shared matters of concern.

Definitions of integration research have also differentiated the concept from interdisciplinary, transdisciplinary and transformative research (Bellon/Nähr-Wagener 2020; Defila/Di Giulio 2018; see chap. 35). Interdisciplinarity generally refers to a process in which researchers from diverse disciplinary backgrounds work together on an object, theme or question. Transdisciplinary research involves not only researchers, but also practitioners whose practices are related to the study. Furthermore, these practitioners must be actively involved as co-researchers, rather than as research subjects or target audiences. Neither of these cognate research areas, however, make reference to the normativity of research practices and configurations.

By contrast, integration research seeks to observe – and possibly enhance – the responsiveness of scientific research and technology development towards societal goods such as environmental sustainability and ethical robustness. Integration research is embedded in a family of normatively oriented research programmes, which are known under the acronyms TA, RRI, (post-)ELSI and ELSA (ethical, legal, social impacts/aspects) as well as VSD (value sensitive design; see chap. 30). It is also closely related to but distinguishable from transformative research (see chap. 35). Both relate research to the pursuit of societal goods. Yet, while transformative research studies and facilitates larger societal transformation processes, such as energy or mobility transitions, integration research tends to engage with the micro-level foundations and conditions that would help to make such transformations possible.

We have so far used ‘integration research’ as an umbrella term encompassing different modes of this research. However, to trace the theory, policy and practice histories of integration, it is important to emphasise distinctions between integration research, integrative research and integrated research. Drawing on Maasen (2021), we place these concepts on a scale ranging from interrogating the possibility of integration, to taking it for granted (Figure 8.1). Integration research is an observational activity, which studies integration as it is taking place in R&D. It examines how differences between ways of knowing, forms of expertise and cultural practices impede, facilitate and shape processes of knowledge production and societal responsiveness. While integration research investigates the possibility of integration, integrative research explicitly facilitates and participates in the process of integration by complementing observation with intervention in the pursuit of knowledge and societal relevance. Interventions entail the design and sustainment of interactions between multiple disciplines with the goal of making differences productive (Zuiderent-Jerak/Bruun Jensen 2007). Integrated research assumes that integration is achievable. It promises that differences can be overcome and frames integration as an activity that has already been completed.

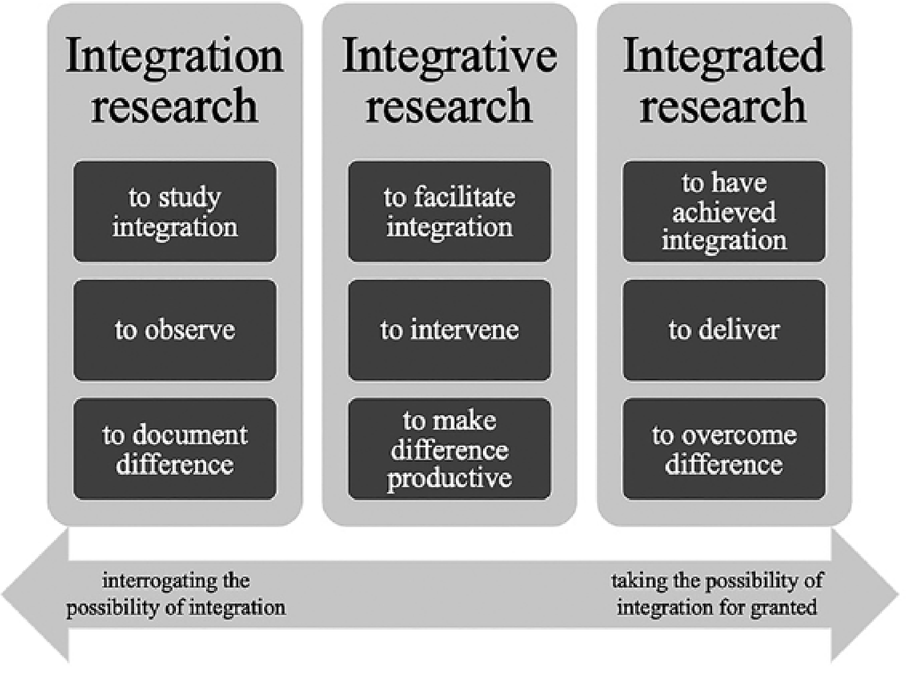

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Figure 8.1 *Different modes of integration research*

THEORETICAL ROOTS OF INTEGRATION: SCIENCE AND TECHNOLOGY STUDIES, SUSTAINABILITY RESEARCH AND APPLIED ETHICS

The different modes of integration research have theoretical roots in science and technology studies (STS), sustainability research and applied ethics. Although these fields are characterised by theoretical heterogeneity, we focus here on specific theoretical strands. In this way, we can map modes of integration research onto these fields so as to foreground the diverging theoretical underpinnings of these modes. Integration research is rooted in classic STS scholarship, which considers integration as an integral part of science and technology. STS concepts such as 'social construction of technology' (Bijker et al. 1987), 'mangle of practice' (Pickering 1995) and 'co-production' (Jasanoff 2004) capture how the social and the technical are always already integrated in actual practices. Empirical research guided by these concepts reveals that modern dualities between technology and society, and between nature and culture, have never existed.

While classic STS literature analyses integration in technoscientific practices, sustainability research posits integration as a regulative ideal (Klenk/Meehan 2015). As sustainability research addresses complex societal and environmental issues, such as climate change adaptation and sustainability transitions, it is positioned at the confluence of science, technology, society and policy. Therefore, research projects often include different academic disciplines and stakeholders (see chapters 34, 35 and 36). In this context, effective sustainability measures are thought to depend on the integration of natural and social science research with local knowledge and values in conceiving research problems, managing a project, analysing data and applying results (Bergmann et al. 2012). Depending on how frictions between different ways of knowing and valuing are dealt with, sustainability research engages in integrative research (exploring the implications of incommensurable knowledge claims and value conflicts for sustainability measures) or integrated research (promising to achieve consensus among different stakeholders and academic disciplines).

In applied ethics, the existence and possibility of integration are objects of ethical discussion and reflection. Ethicists have responded to funding calls for integration by introducing 'ethics on the laboratory floor' (van der Burg/Swierstra 2013). According to Spindler et al. (2020), these activities tend to take two forms: one is to open up room for ethical discussions on intricate relations between technoscientific and socio-ethical dimensions of laboratory routines; the other is to incorporate predefined values into research and technology designs (see chapters 25, 30 and 42). In both forms, applied ethicists combine integration research and integrative research. They probe whether integration exists and/or can be enhanced by embedding ethical reflections in R&D practices.

HISTORY OF INTEGRATION: POLICY AND PRACTICE

Researchers from STS, sustainability research and applied ethics have been involved in shaping the range of research practices, assessment tools and funding instruments that policy-makers have deployed to anticipate and mitigate undesirable societal impacts of new science and technology. These practices, tools and instruments are subjected to the double-bind problem of information and control (Collingridge 1980; see chap. 27). Traditional approaches to parliamentary TA and ELSI or ELSA research programmes face an information problem, because they aim at informing research funding and policies in the early stages of R&D when it is difficult to predict societal impacts. In later stages, when impacts become visible, risk assessment and regulation encounter a power problem, because R&D trajectories are difficult to control or change. To sidestep both problems, a few policy measures target the 'midstream' (Fisher/Schuurbiers 2013), when scientific and engineering activities shape R&D trajectories. Some of these measures implemented in the United States, the European Union and Germany mobilise the language of integration.

Integration in US Legislation

In the United States, the bipartisan 21st Century Nanotechnology Research and Development Act of 2003 required 'integrating research on societal, ethical, and environmental concerns with nanotechnology research and development' (US Congress 2003). Due to concerns about the public acceptance of nanotechnology, policy-makers introduced the Act to avoid repeating the failures of ELSI in the context of genetic and genomic research (Fisher 2019). ELSI was stigmatised as impotent to influence technoscientific outcomes because it worked in parallel to R&D. Having nanotechnology researchers integrate societal studies into their work was thus considered a promising policy response for mediating tensions between the high stakes of the national investment in nanotechnology and the high potential for public controversy over the field (ibid.). In 2005, this response became effective through $6 million in funding from the National Science Foundation (NSF) for real-time TA at the Center for Nanotechnology in Society at Arizona State University. Real-time TA is a cognate of parliamentary TA (see chap. 6), in which 'the social science activities are fully integrated with the core natural science agenda' (Guston/Sarewitz 2002, p. 108). As it targets routine technoscientific practices that have traditionally been shielded from external influences and internal value reflections, it can be considered as an evolution of the ELSI model (ibid.).

Integrating Science and Society in European Funding Solicitations

Post-ELSI policy prescriptions with a focus on integration also emerged in the European Union. According to Rodríguez et al. (2013), policy-makers framed integration as a strategic goal in the inception of the European Research Area in 2000 to ensure that technoscientific innovations would address grand societal challenges and be acceptable to society. As European Framework Programmes were designed to support the creation of the Research Area, these funding solicitations have been pervaded by calls for 'integrating science and society' (ibid.), in particular through the inclusion of industrial partners, socio-economic aspects, social scientists and humanities scholars, and stakeholder voices in R&D processes. The proliferation of integration reached its peak with the introduction of RRI in Horizon 2020, the European Commission's main funding instrument from 2014 to 2020. In response to emphases on integration in research policy and funding programmes, inter- and transdisciplinary practices have been newly developed, and existing approaches (for example, constructive TA; see chap. 27) have been revised (Fisher et al. 2015; Schuijff/Dijkstra 2020).

From Accompanying Research to Integrated Research in Germany

Calls for the integration of societal considerations into emerging science and technology such as nanotechnology, synthetic biology, neuroscience, robotics and artificial intelligence have also appeared on the national level in the Netherlands, Belgium, Norway, the United Kingdom and Germany (Fisher 2019). In Germany, for example, 'integrated research' is a funding concept coined by the Federal Ministry of Education and Research (Gransche/Manzeschke 2020). It is anchored in the high-tech strategy of the federal government, whose 2014 revision stresses that meeting the societal needs for future-oriented solutions to grand societal challenges depends on the participation of civil society in research and innovation activities (ibid.). The concept was introduced to mark a shift from earlier forms of 'accompanying research' (*Begleitforschung*), which have studied societal aspects of technology in separate projects, to research in inter- and transdisciplinary teams (*Integrierte Forschung*) (Spindler et al. 2020). This shift has been supported by the *Cluster Integrierte Forschung*, which develops and implements collaborative approaches to socio-technical integration and critically reflects on their structural conditions in the academic system. Although 'integrated research' appears in the name of the cluster, its members consider their work to be integrative research. Their work is closely related to both constructive TA and STIR, as joint activities by the cluster and the STIR community indicate (for example, the 2023 international twin workshop 'Living the Work of "Integration"').

METHOD OF INTEGRATION: SOCIO-TECHNICAL INTEGRATION RESEARCH (STIR)

Theoretical and practical developments in research have not only followed from, but also preceded and informed, policies on integration. Fisher developed STIR in direct response to the 21st Century Nanotechnology Research and Development Act. Picking up on the notion of 'integration' in the Act, he explored its meaning and associated practices in collaboration with engineering researchers, which resulted in the publication of a pilot study (Fisher 2007). Two years later, with NSF support, STIR was tested in 30 coordinated studies in different countries and research domains. This led to ensuing studies on the discursive, strategic and practical effects of STIR on technoscientific workflows (e.g., Flipse et al. 2012; Schuurbiers 2011). These studies eventually fed back into policy. The NSF subsequently recommended STIR as 'a model for future integration of ethicists and social scientists into nanotechnology R&D laboratories' in its 2011 budget request to Congress (cited in Guston 2014, p. 236). STIR defines socio-technical integration as 'any activity whereby technical experts account for the societal dimensions of their work as an integral part of this work' (Fisher 2019, p. 1139). It assumes technoscientific experts to have a 'capacity' (Fisher 2007) for deliberately integrating societal dimensions into R&D activities, despite the fact that this capacity is typically constrained by disciplinary cultures, structures and logics. In assessing this capacity, STIR probes the possibility of socio-technical integration. As outlined below, it combines three methodological elements – an embedded humanist, a decision protocol and the midstream modulation analytical framework – in two different modes of integration research: STIR 1.0 (integration research) and STIR 2.0 (integrative research).

Embedded Humanist

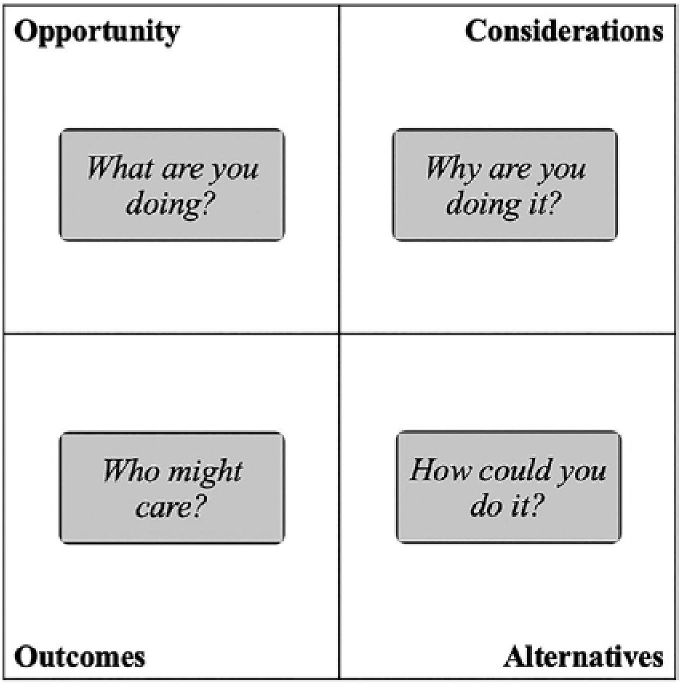
A STIR study usually embeds a social scientist or humanities scholar for a period of 12 weeks into a technoscientific environment to conduct participant observation and regular dialogues with resident experts regarding their everyday work routines. The social scientist or humanities scholar is dubbed the 'embedded humanist' (Fisher/Mahajan 2010, p. 216) to indicate that societal concerns are not brought into a technoscientific team by an external advisor, but emerge through reflexive dialogues within the team. Working in the mode of integration research, the embedded humanist refrains from promoting a normative agenda, and observes how socio-technical integration is achieved, interrogated and altered in technoscientific practices. While technoscientific framings of R&D tend to conceal the socio-cultural orchestration of these processes, the social science or humanities background of the embedded humanist helps them to identify shifts in the modes and practices of socio-technical integration. Based on their observations, the embedded humanist facilitates dialogues inspired by a Socratic mode of inquiry that support scientists and engineers to become aware of and deliberately engage with the societal dimensions of their work.

Decision Protocol

Regular dialogues are guided by the STIR decision protocol. The protocol aims to capture decision-making processes related to technoscientific work practices. It takes routine decisions as the unit of analysis for probing and assessing how technoscientific experts take into account a broad array of ethical, political, environmental, economic and other societal considerations. It further elucidates how decisions could be made differently so as to address and resolve conflicts between different considerations. For this purpose, the decision-making process is structured into four conceptual components: opportunity, considerations, alternatives and outcomes. These components are mapped out on a 2x2 grid (Figure 8.2) to be completed in a collaborative process between the embedded humanist and a technoscientific expert. The embedded humanist guides their collaborator through the process by first identifying an opportunity for decision-making, and then moving clockwise through the grid, while incorporating flexibility for iterations. The decision protocol is thus a probing technique that enables scientists and engineers to reflexively engage with the relations between the social and the technical in everyday work, and to cultivate their capacities for such reflexive socio-technical integration.

Midstream Modulation

The midstream modulation analytical framework traces change over time in how technoscientific practitioners engage in socio-technical integration (Fisher/Schuurbiers 2013). 'Midstream' refers to the stages of R&D that are positioned in relation to 'upstream' agenda-setting and 'downstream' regulation of new science and technology (p. 99). In these stages, scientists' and engineers' interactions with societal considerations can be related to 'midstream modulations': gradual alterations of research and technology trajectories (ibid.). These alterations can be analysed into modulation sequences. De facto modulation is any instance when societal considerations play a role (usually implicit) in technoscientific practices. Technoscientific experts pass on to reflexive modulation when they become aware of such de facto modulation



Source: © Erik Fisher.

Figure 8.2 STIR decision grid

and the agency they have in shaping it. In response to reflexive modulation, they may change strategic, discursive or material practices. Instances of such change, which are identified as deliberate modulations, are often co-created with the regular use of the decision protocol. Modulation sequences are commonly used by embedded humanists to analyse the empirical documentation of STIR studies.

STIR 1.0 and STIR 2.0

The foregoing description focuses on the classic version of STIR, also referred to as STIR 1.0, which has been applied in more than 80 studies. In the STIR pilot study, for instance, Fisher (2007) documents a modulation sequence of a nanotechnology researcher who, over the course of regular STIR dialogues, became aware of contamination and disposal concerns about an experimental catalyst, which the researcher subsequently replaced with a more environmentally benign alternative. Flipse et al. (2012) deployed STIR in industrial contexts, where biotechnology researchers initially placed societal considerations outside the bounds of their professional responsibilities. Through regular interactions with the STIR decision protocol, they came to consider reflexive engagement with these considerations as ‘part of the job’ of researchers in industry. In these examples, what considerations emerged in STIR dialogues was a function of what the technoscientific researchers chose to discuss.

In STIR 2.0, an underdeveloped application of the method, societal considerations can be introduced by the embedded humanist. STIR 2.0 is an example of integrative research which intervenes in R&D processes and participates in socio-technical integration with a view to orienting it towards preferred or predefined values. An embedded humanist working with STIR 2.0 may appeal to values beyond what their technoscientific collaborators have already mentioned. Hence, reflexive and deliberate modulations advancing these values in discourse, strategy or practice are intended outcomes. In STIR 1.0, by contrast, reflexive and deliberate modulations are considered as side effects of using the decision protocol for assessing the possibility of socio-technical integration.

Few, if any, published studies have included STIR 2.0 in their design. Frost et al. (2022) pursue a mode of STIR 2.0 in which the embedded humanist refers to values and tensions that were inscribed in the research framework of their technoscientific collaborators. In other studies (Branch/Duché 2022; Smolka et al. 2020) instances of STIR 2.0 result from the affective agitation of the embedded humanist in the context of a STIR 1.0 study and gave rise to modulation sequences widening the socio-ethical horizons of technoscientific experts. Future research could test the potential of STIR 2.0 designs to integrate specific values into R&D.

RESEARCH ON INTEGRATION: EMERGING AVENUES FOR FUTURE STIR STUDIES

Further avenues for future studies lie in developing STIR applications in TA. While STIR is largely a lab- and project-level approach (for one among several exceptions, see Richter et al. 2017), integration in TA tends to focus on the field level of research and technology development. Constructive TA, for example, recognises that researchers not only work at the lab bench, but also move across contexts, participating in public–private partnerships and policy advice (see chap. 27). Moreover, many socio-ethical impacts of technology development emerge when technologies leave the lab, enter industrial logics of scaling and diffuse into society. The socio-ethical aspects of technoscientific practices are thus not restricted to the lab work of a specific research group, but are better understood as features of larger systems, in which a diversity of actors cooperate. To build integrative capacities in socio-technical systems, Smolka and Böschen (2023) suggest that STIR could be combined with TA approaches. By developing a STIR application in TA, they advance a 'systemic turn' (p. 1) in integration research.

Integration research travels not only from the lab to larger systems, but also from the Global North to the Global South. Emerging STIR research thus widens and diversifies the empirical contexts to which the method can be applied. STIR studies have been conducted in over 20 countries, including the United States and Australia, and in Europe and Asia. Recently, García and Puga-Gonzáles (2022) conducted the first STIR study in Latin America, highlighting the challenges they faced in 'STIRring' research groups in Mexico. They examine an 'incarceration triad' of funding, bureaucratic structures and regime policy changes specific to Latin American contexts that makes it harder for local actors to engage in reflexive socio-technical integration.

Furthermore, STIR could be diversified by efforts to 'transduct' (Doezema et al. 2019, p. 325) the method. STIR could extend and reconfigure theoretical and methodological approaches so as to support various goals that local contexts have set for themselves, moving into a mode of integrative research that would seek to 'facilitate improvements' (Fisher et al. 2015, p. 46). Another example of how STIR could reconfigure itself is Smolka and Fisher's (2024) study with contemplative scientists, who both study and practice Buddhist meditation. In this community, attending to embodied knowledge and ethical sensitivity turned out to be an important element of STIR dialogues. In transducting STIR, future research could shed light on the heterogeneity of epistemic communities involved in R&D while also drawing on their vernacular strengths for pursuing socio-technical integration.

Finally, future research needs to continue assessing the carriers and barriers of socio-technical integration in science and technology development (see chap. 3). Whereas some research gives the impression that barriers to integrative research can be insurmountably high (e.g., Frost et al. 2022), such studies make valuable contributions to integration research by enhancing our understanding of the conditions that facilitate or impede reflexive and deliberate forms of socio-technical integration. This understanding is important to support a wider cultural change in modern science and technology (Maasen 2021). In this chapter, we have shown that this change is already under way, as socio-technical integration has infused multiple interrelated levels and arenas of R&D, whilst also spreading across the globe. Future efforts to work in the integrative field may themselves help to reach a point where reflexive socio-technical integration will be embedded in institutional infrastructures, social norms and epistemic paradigms prevailing in research and innovation cultures.

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