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RESEARCH ARTICLE



Putting Embedded Ethics and Social Science into practice: the role of peer-to-peer relationships

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ABSTRACT

In response to the ethical and societal challenges of emerging technologies, there is a growing commitment to integrative socio-technical research. One such approach is embedded ethics and social science, which embeds the analysis of ethical, social, and legal aspects into the entire innovation process through direct collaboration between ethicists, social scientists, legal scholars, technical researchers, and experts in the field of application. We offer reflections on our experiences from the approach's pilot project, Responsible Robotics, where we were integrated into a research project on service robotics for senior care. Drawing on more than four years of embedded research, we present practices through which peer-to-peer relationships develop. These relationships challenge disciplinary identities and serve as grounds for mutual learning and capacity-building. Our insights contribute to the discourse on how science and technology studies (STS), ethics, and law can integrate with technological research to ensure ethically and socially responsible practices.

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Introduction

The ethical implications of introducing new digital technologies in healthcare are multifaceted, encompassing concerns about patient safety, autonomy, privacy, the equitable distribution of benefits, and more (Vayena et al. 2018). In robotics, these issues are exacerbated due to direct physical interaction with patients, highlighting concerns

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about their reliability and safety, especially when used with vulnerable people such as in elderly care, as well as the potential loss of human and personal touch in healthcare (van Wynsberghe 2016). These ethical aspects necessitate comprehensive reflection to ensure responsible integration and use of robotic technologies in medical settings.

In response to the challenges and ethical considerations of emerging technologies, there has been a growing commitment to fostering integrative socio-technical research within academic institutions. In this paper, we reflect on our collaboration to achieve such integration to address the ethical, social, and legal issues arising during the development process of a humanoid service robot for geriatric care. Over the course of more than four years of collaborative effort, we designed and conducted a project entitled 'Responsible Robotics (RR-AI): Tracing Ethical and Social Aspects of AI-Based Transformations in Healthcare Work and Knowledge Environments', funded by the Bavarian Institute for Digital Transformation (bidt). We employed an embedded ethics and social science approach (McLennan et al. 2020; Breuer et al. 2023) to integrate the analysis of social, ethical, and legal dimensions into the practices of a research initiative in robotics and artificial intelligence (AI). In doing so, we follow the calls for further practitioner reflections on collaborative socio-technical integration (Mehnert, Fischer, and Ammon 2023; Balmer et al. 2015, 2016; Boenink 2013). We share reflections on our experiences as an integrative team of researchers from STS, ethics, law, and robotics.

This is a salient case for reflections on socio-technical collaboration because in AI and related fields more engaged socio-technical approaches are only recently emerging. Decades of experience with research on the ethical, legal, and social implications/aspects (ELSI/ELSA), responsible research and innovation (RRI), and socio-technical integration in fields such as neuroscience (e.g. Fitzgerald and Callard 2015), synthetic biology (e.g. Balmer et al. 2015; Rabinow and Bennett 2012), and nanotechnology (e.g. Viseu 2015; Fisher and Maricle 2014) have revealed the affordances of participatory and integrated socio-ethical research as a means of governing emerging technologies and the innovation ecosystems that surround them (Smolka and Bösch 2023). However, the currently booming field of AI has mainly fallen back on self-regulation, often via principle-based ethical guidelines (Braun and Müller 2024; for overviews of ethical guidelines for AI, see Jobin, Ienca, and Vayena 2019 and Fjeld et al. 2020). In the face of an ever more evident gap between principles and practice (Morley et al. 2020; Mittelstadt 2019), we seek to advance the embedded ethics and social science approach as a complement to abstract, principle-based AI governance. The embedded ethics and social science approach is in step with more recent strides in the European Union (EU), such as the new EU AI Act¹, toward more active political governance of AI.

We contribute in-depth reflections on our practical experiences of conducting the Responsible Robotics project to build on the literature about embedded ethics and social science, which has largely described the approach and its methods theoretically (McLennan et al. 2020; Tigar 2022). A particularly central element in our collaboration was the relationships we built among ourselves. Engaging with broader debates on how embedded researchers relate to their host socio-technical projects (Fisher et al. 2015; Balmer et al. 2016) and inspired by the theme of this special issue, we ask: How were collaborative relationships developed in our project, and what insights can be gained for fostering the integration of ethics, law, and social science into technological projects? The relationships we will discuss are not exhaustive or exceptional; rather, they represent

typical dynamics in cross-disciplinary collaborations in situated practices and moments. Following Müller and Kenney (2014, 543), we will use the term ‘peer-to-peer relationship’ to describe the trusting and collegial connections that can develop between academic peers from different disciplinary backgrounds.

Our contribution is unique for its joint reflection across four disciplines, contrasting with previous reflections that often come solely from integrated ethicists, ethnographers, or social scientists (e.g. Viseu 2015; Rabinow and Bennett 2012). While some studies have included joint reflections with engineers or scientists (e.g. Lee et al. 2019), our work brings together perspectives from STS, ethics, law, and technology, reflecting levels of togetherness rarely addressed, e.g. between STS and ethics or law scholars. By sharing these insights, we aim to advance the discourse on integrating STS, ethics, and law with technological research to promote socially and ethically responsible innovation.

Background: socio-technical collaboration

As one of the research strands concerned with the governance of the relationship between technoscience and society, there has been a long-standing history of social science research on and with other experts, including most notably scientists and engineers (early examples include Latour 1987; Haraway 1991; Rabinow 2004). Fisher et al. (2015, 39) have called this field of study ‘collaborative socio-technical integration,’ which puts a focus on the practices of technoscientific experts and their relations to their social context (Fisher et al. 2015, 41). An emphasis on existing efforts is put on building experts’ ‘capacity’ to reflect on their roles and responsibilities in accounting for the societal dimensions of their work (Fisher 2007, 155; Fisher and Maricle 2014). A variety of approaches and methods have sprung up that share a commitment to science and technology governance and reflexivity ‘from within,’ among them notably socio-technical integration research (STIR) (Fisher et al. 2015), making and doing (Downey and Zuiderent-Jerak 2021), co-laborative ethnography (Niewöhner 2016; Bieler et al. 2021), and embedded ethics and social science (McLennan et al. 2020; Breuer et al. 2023).

Individual projects vary widely, and efforts have been made to map different approaches. Fisher et al. (2015) and Fisher (2019) propose a framework based on forms of integration, means, ends, and sources of values and capacities. Forms of integration determine whether societal aspects are seen as inherent within a technoscientific domain or introduced by integrated researchers. They also distinguish if projects are embedded within their focal domain or operate separately and their level of dependency on the domain. Means of integration refer to methods used and their flexibility. Ends of integration focus on the values driving an approach, whether advancing the technical project’s goals or advocating for value adjustments. Fisher et al. (2015) map collaborative socio-technical integration projects using a matrix of values and capacities, identifying four ideal-typical modes: ‘reform,’ ‘problematization,’ ‘augmentation,’ and ‘facilitation’ (Fisher 2019, 199; Fisher et al. 2015).

Integrative research approaches have faced extensive reflection and critique, often from integrated researchers themselves. A common concern is a certain silence in the literature about clear effects and outcomes of integrative research, especially regarding practical changes within technoscience (Rip 2009; Fisher 2019). Integrated researchers

observed challenges related to ‘collision[s] of normativities’ (Moats and Seaver 2019), disinterestedness of scientists and engineers (Rabinow and Bennett 2012; Lee et al. 2019), and power asymmetries (Doubleday and Viseu 2009; van Oudheusden 2014) undermining meaningful integration and influence on expert practices.

Critically, integrated social scientists often find themselves marginalized. As integrated social scientists, Fisher et al. (2015, 711) found themselves in a dishonest relationship vis-à-vis the scientists they worked with, which the authors describe as ‘deceptive,’ where they had to avoid openly addressing problems and harming their research. Viseu (2015) criticizes the relegation of integrated researchers to a role of caring for a technology without meaningful interaction with the research process, leading to the devaluation of their expertise. Moats (2021, 19) argues that traditional roles and technocratic routines of interdisciplinarity lead to dry exchanges that may ‘paper over many potential sources of tension’ but, by doing so, ‘prevent more radical mixings.’ This leads to situations where integrated researchers sometimes find themselves in a ‘subordination-service’ relationship toward their host labs, pressured to produce deliverables for grants and support technology commercialization (Barry, Born, and Weszkalnsy 2008).

While the roles of ‘co-constructors of scientific fields’ (Calvert 2024) and ‘co-producers of knowledge’ are important aspirations, their practical implementation is often challenging (Balmer et al. 2015). Practical hurdles and feelings of discomfort arise when social scientists realize that the reasons why technical scientists invite them differ greatly from their own reasons for wanting to collaborate (Calvert 2024, 5). Many of the criticisms imply that collaboration will not be fruitful if technical collaborators are not convinced of the same goals as their embedded counterparts.

However, other scholars have advocated for embracing what researchers can do together even without a priori-defined shared aims for specific outcomes. They have described differences in goals and the tensions they generate as both challenging and productive for collaboration (Rommetsveit 2019; Balmer et al. 2015, 17; Moats 2021). Niewöhner’s (2016, 5) ‘co-laboration’ is an approach that explicitly emphasizes not a joint goal, but a ‘shared process of labor’. Co-laborators conduct joint epistemic work and experiment with methods and formats without necessitating alignment on a unified political or epistemic aim. This relational practice fosters reflexivity, enabling collaborators to think differently and bring new perspectives back to their home disciplines (Bieler et al. 2021; Niewöhner 2016).

To cultivate more fruitful epistemic partnerships in challenging circumstances, practitioners have emphasized the merit of open-ended approaches to socio-technical integration. They emphasize experimentation (Niewöhner 2016; Fitzgerald and Callard 2015; Delgado and Åm 2018), play (Balmer et al. 2016; de Saille et al. 2022), informal communication (Aicardi, Reinsborough, and Rose 2018), humor and irony (Moats 2021), and advocate for flexibility in role-taking. Integrative researchers benefit from acting as ‘chameleons,’ dynamically shifting between diverse roles along the collaboration process (Balmer et al. 2015).

Against this background, we can understand roles and relationships within collaborative socio-technical research as multifarious and situated. The question of how embedded researchers relate to their host socio-technical projects remains contested, indicating the ongoing need for further exploration. Our contribution adds to the

body of research examining the formation of collaborative relationships across interdisciplinary experts. We discuss a particular mode of interaction – the peer-to-peer relationship. Drawing on the work of Müller and Kenney (2014, 543), who analyzed how qualitative interviews can create a ‘peer-to-peer relationship’ between interviewing social scientists and interviewed life scientists, we explore how these relationships foster care and responsibility, leading to reflective and adaptive research practices. Building on their insights and extending them to long-term collaborative socio-technical initiatives, we present a case study from our own project, analyzing the relationships we developed and how they enabled and constrained our epistemic work.

Our study represents the first in-depth reflection specifically on the practices of using the embedded ethics and social science approach within a robotics and AI initiative. Early projects about integrating ethics and social science into engineering and data science labs encountered various challenges. Social scientists integrated into these environments often found their normativities collide with those of engineers and data scientists, navigating engineering cultures that tend to disengage from ethical deliberation and critical work (Lee et al. 2019; Moats and Seaver 2019). Researchers of the Ethics and Society Programme of the Human Brain Project highlighted challenges in building trust relationships with technical researchers and finding mechanisms to actually influence the directions of the large-scale project (Aicardi, Reinsborough, and Rose 2018, 28f). Further projects have since emerged, using various approaches such as the integration of critical data studies with data science (Moats 2021; Neff et al. 2017); ethical deliberation for agile processes (EDAP) (Zuber et al. 2024); and embedded ethics and social science (Willem et al. forthcoming; Jörg, Ziehmman, and Breuer 2023), upon which the present paper reflects.

Approach: embedded ethics and social science

Our research builds on McLennan et al. (2020) ‘embedded ethics’ approach, which has since evolved into the ‘embedded ethics and social science’ approach (Breuer et al. 2023; Willem et al. forthcoming). This more accurate rebranding reflects the equal importance of ethical and social scientific analysis in this approach and highlights the deepening collaboration between these disciplines in our integrative work (Willem et al. forthcoming). In essence, embedded ethics and social science denotes ‘the practice of integrating the consideration of social, ethical and legal issues into the entire development process in a deeply integrated, collaborative and interdisciplinary way’ (McLennan et al. 2020, 1). It constitutes an empirical, bottom-up approach to studying ethical, social, and legal issues as they arise within research and development practice (Breuer et al. 2023). The approach envisions ethicists, social scientists, legal scholars, and engineers working together as partners in a team, developing practical tools and interventions to analyze and address identified issues, and co-designing applications of emerging technologies (Breuer et al. 2023; Tigard et al. 2023).

The approach draws from multiple disciplinary traditions, reflecting a mix of influences. Its philosophical roots originate from applied ethics, where ethicists apply ethical theory to specific science and technology development processes to foster ethical deliberation (van den Hoven, Miller, and Pogge 2017; van der Burg and Swierstra 2013). It is similarly rooted in approaches that are part of the ‘engaged program’ of

Science and Technology Studies (STS) (Sismondo 2007), which merges the analysis of science and technology as socio-cultural practices with an ambition to participate in democratizing these practices. These approaches have resonances with ‘co-laborative ethnography’ (Niewöhner 2016; Bieler et al. 2021), which emphasizes joint epistemic practices and foster reflexive moments about disciplinary positionality and responsibility regarding societal dimensions. Further, our embedded research has roots in embedded law, where integrated legal scholars actively participate in shaping technology development processes (Witz et al. 2024). These diverse disciplinary foundations share values of social justice, equity, and harm reduction and provide us with a diverse array of perspectives and techniques to advance the aspiration of making science and technology more societally reflexive and responsible.

Project, case, and methods: responsible robotics

We report on the ‘Responsible Robotics’ project, conducted between 2020–2024 at the Technical University of Munich (TUM) and funded by the Bavarian Institute for Digital Transformation (bidt). It was collaboratively led by the Professorship for Science and Technology Policy, the Institute for History and Ethics of Medicine, the Munich Institute of Robotics and Machine Intelligence, and the Professorship of Innovation and Public Law at the University of Vienna. From each of these institutions, Responsible Robotics had one to two researchers on the graduate or post-graduate level who participated in the day-to-day integrative work.

Our team was integrated in the Lighthouse Initiative Geriatrics (‘Geriatrics Initiative’ henceforth), which served as our case study and host technological initiative. Unlike many socio-technical integration and embedded ethics and social science projects that involve a single embedded researcher, we had a whole team of multiple STS researchers, medical and technology ethicists, and legal scholars working with the Geriatrics Initiative. Additionally, two robotics researchers from the Geriatrics Initiative were equal team members of Responsible Robotics, funded through our grant. They acted as mediators, or ‘brokers’ (Wenger 1998; Smolka and Bösch 2023), facilitating interactions with the Initiative’s researchers and the broader ecosystem of stakeholders, utilizing their field-specific capacities within the host initiative while dedicating their time to the embedded project.

The Geriatrics Initiative was launched in 2018 by TUM’s Munich Institute for Robotics and Machine Intelligence (MIRMI). During our collaboration, the team comprised 19 PhD candidates and post-docs from various engineering and computer science fields, supervised by six Principal Investigators (PIs). The Initiative focuses on using robotics and machine intelligence in geriatrics and gerontology to support and enhance self-determination in old age (MIRMI 2020). It aims to advance foundational robotics research and develop robotics applications for healthcare, including residential settings, assisted living facilities, nursing homes, and hospitals, targeting a diverse user base, such as older adults, patients, physicians, physiotherapists, and nurses. The flagship project, GARMi, is a humanoid service robot designed as a research platform for emergency assistance, diagnostics, telemedicine, and rehabilitation (Figure 1; Tröbinger et al. 2021). Besides technical research and development, the Initiative includes work packages on public outreach and education.



Figure 1. Assistant robot GARMi (photo: Kurt Bauer/TUM MIRMI).

Responsible Robotics joined the Initiative two years after its launch. Consequently, we missed the first formative stages of the Initiative and its technologies. However, we entered when the group was working on their first prototype of GARMi, which was still an early phase of technology development. This timing allowed us to influence design choices while having concrete technologies and use cases to start ethical, legal, and social reflections and to iteratively integrate these considerations into the ongoing development process.

Our self-understanding as collaborators is rooted in the belief that all our fields are inherently reflexive and aware of societal dimensions (cf. Niewöhner 2016). Not only do STS, ethics, and law bring to bear their diverse reflexivities on societal dimensions of robotics and AI research, but so do robotics and AI fields themselves. The Geriatrics Initiative is actively engaged with the societal context of its technical research, as evidenced by its major visions for transforming senior care, its involvement in developing training programs for nurses, and its engagement with local care providers. Therefore, we see societal dimensions as latent within and inherent to the activities of the Geriatrics Initiative. Thus, our task was to clarify, rather than introduce, their research's already intertwined technical and societal dimensions (cf. Fisher et al. 2015, 48), particularly their relationship to healthcare domain knowledge.

Responsible Robotics's integration into the Geriatrics Initiative achieved a high degree of embeddedness through frequent exchanges, phases of co-location, and a shared commitment to collaboration. We established a structure of weekly meetings for Responsible Robotics members and quarterly meetings for the entire team. Over the course of more than four years, we went through phases of understanding our host initiative's practices, experimenting with small 'co-laborations' (Niewöhner 2016), and interventions. We familiarized ourselves with the Initiative's practices through 'peer-to-peer interviews' (Müller and Kenney 2014), onsite visits, and virtual meetings, especially during the Covid-19 pandemic. We participated in

milestone, integration, and sprint meetings of the Initiative, where we observed, engaged in discussions, presented our research, and received feedback. As restrictions were lifted, lab visits and in-person interactions deepened our understanding of the practical aspects of Geriatrics research and facilitated collegial relationships. We embraced opportunities for smaller collaborations, such as organizing workshops and co-teaching classes. These smaller collaborations helped us build a relationship of mutual trust and understanding that allowed us to perform more comprehensive interventions into the Initiative's research practices by conducting a collaborative research study, which we will describe in more detail below.

While we were embedded into the practices and infrastructures of the Geriatrics Initiative, we were relatively independent. We did not have to rely on our host Initiative for funding. Moreover, our bid grant offered independence to the different disciplines involved by providing funding separately, in an equal split, to the chairs involved, making them financially independent from each other. It is important to acknowledge that the development of a highly embedded work relationship was made possible by a supportive institutional environment at our home universities. TUM has been putting increasing emphasis on the collaboration between social and technical sciences and is assuring long-term support for collaborations beyond individual research projects (TUM Campus News 2022).

Experiences: building peer-to-peer relationships in collaborative practice

In the following analysis, we revisit the work of the Responsible Robotics project, reflecting on the particular relationships we built as collaborators. We were academic peers engaged in the joint development of knowledge, technological artifacts, and reflexive sensibilities. Following Müller and Kenney (2014, 543), we call our relationships 'peer-to-peer,' drawing attention to how collaborators' shared membership in the academy allows privileged access to their epistemic living spaces and practices by generating mutual trust based on assumed similarity of experiences. On the level of groundwork, we share similar ambitions of making academic contributions, developing research skills, and advancing our careers. For example, between PhD candidates, we sometimes bonded by commiserating on the struggles of doing a PhD and celebrating each other's achievements along this journey. And while our specific epistemic interests and goals for research differ, e.g. in terms of the levels of investigation and analysis that interest us most or the venues in which we want to publish, we align on a shared ambition to find more societally responsible ways of doing robotics. In the following, we will share vignettes of collaborative practices within Responsible Robotics that illustrate the particular relationships we have built over time.

Building workable relationships in modest experimental co-laborations

As in many other integrative projects (Fitzgerald and Callard 2015; Niewöhner 2016; Moats and Seaver 2019; Estalella and Criado 2018), a central element of our collaboration has been experimentation. Embracing an openness to opportunities for serendipitous collaboration, we mutually followed each other's invitations to do small joint projects together. These projects were motivated by our shared interest in public outreach and engagement and the desire to learn about each other's approaches. While we were

each other's guests in the sense that we followed each other's invitations, this relationship was characterized mainly by joint exploration – as if we were an assorted expedition team on paths that took all of us out of our respective everyday work environments and practices. We give two examples of such explorative expeditions and discuss how they constituted specific forms of collaboration and affected our relationships.

One of our small co-laborations was exhibiting at a fair together. The Geriatronics Initiative invited our STS and ethics team members' contribution to the *automatica* (2022 in Munich, Germany), a trade fair at which the Initiative has been a recurrent exhibitor. In this collaboration, we straddled between roles of advocating for responsible robotics and spontaneously investigating corporate and commercial stakeholders relevant to our host Initiative. Within the *automatica*'s expansive *munich_i* AI.Society area, we were positioned alongside other booths affiliated with the Geriatronics Initiative. We shared our booth with an NGO concerned with the standardization and assessment of 'ethical and trustworthy artificial and machine intelligence' known as *etami*. Notably, we were the only booth devoted to socio-ethical aspects amidst this fair, which predominantly centered on technical and commercial dimensions. The role thus implicitly ascribed to the STS and ethics scholars at the booth was to represent ethics or society. While we could contest this role for reasons outlined in Balmer et al. (2015), we chose to embrace it, recognizing the opportunity to elevate the visibility of ELS aspects within the discourse surrounding robotics and automation. Further, the *automatica* became a spontaneous opportunity for fieldwork, where we, outside our usual fields, got to investigate questions of the integration of ethics into industry practice – a theme that had motivated our project from the start. Speaking to company representatives from the automation industry at their booths, we uncovered practices, processes, or organizational entities they associate with the term ethics; while the concept of ethics is recognized to some extent by representatives of private sector companies, its incorporation into business practices and discourse appeared limited (Braun et al. 2022b). These experiences affirmed our collaborative relationship by underscoring the necessity of interdisciplinary collaboration that addresses this gap between theoretical discourse and practical implementation to facilitate the development of more nuanced and contextually relevant ethics practices that resonate with industry realities. The experience demonstrated that even collaborations that initially appear to primarily support the host initiative can provide embedded researchers with opportunities to pursue their own research interests simultaneously.

Further, team members from all four of our disciplines developed and co-taught a Project Week on responsible robotics (2023). The Project Week is a new teaching format that is being established at TUM as part of its Excellence Strategy. Its goal is to enable students to find approaches in complex problem solving, to develop reflexivity, and to work productively in heterogeneous teams, through an experience of integrative project-based learning (TUM 2024). In our project week, 20 students from different disciplines, spanning from the engineering sciences, natural sciences to social sciences, and law, attended. We convened in Garmisch-Partenkirchen for four days, where we had access to the Geriatronics research center facilities. Robotics researchers gave demos of prototypes and engaged with the students. Experts from law, social science, and robotics gave lectures and formed a jury that evaluated student projects. For their projects, the students were matched together in interdisciplinary groups of four and were tasked to

identify a use case in (health)care robotics, analyze its ethical, legal, and social aspects, and develop a proposal for an interdisciplinary research project. This shared teaching experience not only provided us with new insights into each other's approaches and perspectives, but it also transformed into an immersive team retreat that strengthened our collegial bond. While the students engaged in their group work, we also collaborated closely, outlining multiple research projects and generating ideas for papers that we later pursued together, including a collaborative study that we will detail below (see 'Finding a focus point for collaborative research').

These were but two examples of the diverse and admittedly eclectic engagements that characterized our project's early stages. While these temporary and modest engagements did not bring about any significant transformations in our usual research practices, they nevertheless were instrumental in getting to know each other. By temporarily diverging from our typical disciplinary approaches and embracing new modes of collaboration, these encounters provided opportunities for reflection and enhanced interpersonal relationships.

Engaging knowledge holders in the application domain

A central focus of our collaboration revolved around our respective interests in engaging domain-specific expertise. In initial interviews and interactions with the Geriatrics researchers, we learned about the particular challenges they face as researchers of a highly specialized technical field (i.e. robotics) while at the same time needing to incorporate specialized knowledge about the domain they aim to develop applications for. Notably, the Geriatrics Initiative's explicit mission involves supporting healthcare workers through assistive robotics. This raises questions regarding how to integrate knowledge about this specific social and professional context and our respective roles in that endeavor. All of us integrative researchers needed to learn about and consider the intricacies of the healthcare domain. Most of our team members started from a foundation of limited prior knowledge, except for our medical ethicists, who had considerable experience working within healthcare. Consequently, considerable parts of our efforts went into research about the practices and perspectives of healthcare workers, through a combination of parallel, facilitative, and collaborative efforts.

The initial phases of our project included efforts where both the Geriatrics Initiative and the Responsible Robotics team were engaging healthcare professionals' perspectives in parallel. Our STS and ethics researchers conducted qualitative interviews with nursing scientists and healthcare practitioners from various medical and nursing professions. We also interviewed the Geriatrics team about their ongoing engagements with the healthcare domain and joined some of these engagements as non-participant observers. As we have described in more detail in Breuer et al. 2023, we identified two ways domain-specific knowledge was integrated: through robotics researchers consulting healthcare experts and through robotics researchers gaining first-hand experience, such as interning at nursing homes. While we saw tentative uses of both approaches, the greater part of the Geriatrics Initiative's engagement with healthcare stood in tension with both approaches because it strongly focused on 'acceptance.' Efforts to collect participant input were often combined with educational activities, e.g. engagements with employees of a local care provider or in the classroom of a nursing school. In these engagements, robotics researchers showed participants informational videos about recent research in

the lab, emphasized that there is nothing to fear about interacting with the robot, and instructed participants to operate a robot arm in a simulated telemedical examination. While the robotics researchers emphasized the importance of participant feedback, the chief exercises of the engagements were geared toward alleviating healthcare practitioners' assumed fears to ensure future uptake.

Our observations led our STS and ethics researchers to step away from the role of observers and into the role of critics when we started problematizing the narrow acceptance frame used for healthcare expert engagement. Drawing on long-standing critiques within STS regarding deficit model framings for public engagement (Wynne 1991; 2006; Irwin 2001), we contended that engagement formats centered on acceptance are insufficient for eliciting domain-specific knowledge. Such formats constrain participant contributions by relegating them to passive roles and limiting how much can be learned from their perspectives (Breuer et al. 2023).

Therefore, we sought to complement and broaden our host initiative's capacities for engaging with healthcare-specific expertise. Our own studies with healthcare professionals and academics could complement and inform the efforts of the Geriatrics Initiative. At the same time, we sought to break away from this traditional division of labor where the social scientists take on the task of researching the social domain with minimal involvement of the robotics researchers in this process. To bring the robotics researchers together with healthcare workers directly and facilitate exchange, our STS team initiated a deliberate intervention: a LEGO® Serious Play® Workshop facilitated by Stevienna de Saille. The participants, three robotics researchers, and three nursing experts engaged in creative exercises aimed at collectively envisioning a future for healthcare robotics. Being prompted to build small LEGO® models alongside their discussion helped them to move beyond their usual disciplinary patterns of thinking, which was particularly crucial for opening up these two expert groups' perspectives. The approach redirected the focus of reflection to the values that should govern robot design rather than specific design details (de Saille et al. 2022). Although modest in scale, these engagements planted seeds for enhancing the robotics researchers' openness to the knowledge, concerns, and values articulated by healthcare practitioners and their capacity to respond to them. For our peer-to-peer relationship, this was a move toward bridging disciplinary divisions of labor and laid the groundwork for expanded collaborative efforts involving healthcare-specific expertise.

Finding a focus point for collaborative research

Our regular exchanges and experiences of small experiments with integration helped us develop a relationship of trust and mutual understanding that allowed us to create a more extensive and ambitious research agenda together. Most notably, even beyond the funding duration of Responsible Robotics, we have been working on a collaborative research study aimed at integrating social, ethical, and legal aspects with the design features of GARMI. While lasting longer than the small projects, this endeavor was no less experimental and open. We collectively ventured into research-practical terrain that stretched the boundaries of our respective usual practices. This integrative GARMI study highlights the benefits of being flexible in shifting between different forms of integration, specifically between problematizing, augmenting, and facilitating as modes of interaction (cf. Fisher, Mahajan, and Mitcham 2006).

Motivation for the integrative GARMI study was to move beyond topics of user acceptance toward questions of what it could mean to involve diverse stakeholder perspectives into the robot design. Thus, our study design was partly inspired by problematizations we had made earlier in the project. For the study's research question of 'How can we design service humanoid robots in a more responsible way?', both our Responsible Robotics team and the Geriatrics Initiative have had a great interest in including stakeholder feedback. To overcome the limitations of acceptance-focused stakeholder engagement, we augmented the Initiative's capacities by offering skills and considerations from our diverse expertises. At the same time, we remained within the Initiatives' local problem-framing, i.e. stakeholder involvement. We held multiple internal workshops in which we developed a design for the integrative GARMI study that involved gathering perspectives of relevant stakeholders and the general public; social, ethical, and legal analysis; and deriving insights for the future design of GARMI. The responsibilities for leading the different parts of the study were loosely divided along traditional disciplinary lines, but the research efforts were by no means isolated activities.

We collected stakeholder perspectives via a focus group study, which we approached as a highly integrative endeavor. Our STS team members took on a facilitating role for the shared effort, and researchers from all our four fields were involved in designing and conducting the focus groups. In an effort to learn about the relevant social science methods, our researchers from law, ethics, robotics, and STS took a workshop on scenario-based focus groups offered by the STS department at TUM. We used the practical part of the workshop to begin workshoping the scenarios for our study. Designing the scenarios, we ensured they represented current research within the Geriatrics Initiative to receive participants' valuations (Braun et al. 2022a) and include steps of intensification that allow insights into differential normative judgments of the participants. Researchers from STS and law conducted the focus groups, engaging healthcare workers from various professions and members of the general public in scenario-based round table discussions.

We learned a lot from our focus group study experience, but we want to highlight an unexpected challenge we faced. Despite designing the study to gather insights that can inform the design of GARMI, achieving this goal proved challenging. During focus groups with members of the general public, participants often deviated from discussing our concrete, mundane, research-derived scenarios, instead veering into speculative discussions about artificial general intelligence (AGI), superintelligence, or care robots entirely replacing human nurses – topics that fall outside the scope and focus of our study on assistance robotics. Consequently, obtaining responses relevant to ongoing technical research endeavors within the Geriatrics Initiative was more challenging than anticipated. This seemed like a larger setback for the robotics researchers among us, mainly concerned with object-level questions of robot design, than for our colleagues from STS, who are more inclined toward meta-level reflections. Indeed, our team members from STS appreciated the opportunity to reflect on their methods. They consider these observations worthwhile findings in themselves that point us toward the challenges that come with doing imaginative participatory design research in a time when pervasive media narratives capture the public imagination. Despite this challenge, the focus groups, especially the ones with healthcare professionals, nevertheless yielded valuable insights that informed design considerations for GARMI.

Working on robot design forced us to synthesize all our perspectives – a process in which, again, all of us were challenged to step outside our usual practices. We decided to combine insights from our stakeholder interviews and focus groups with ethical and legal analyses and technical research to derive technical requirements for GARMi. Our members from STS, ethics, and law opened up to working within the practices, approaches, and logics of robotics research – in this sense, serving a facilitative function toward the goals of our host initiative. In combining our capacities, we achieved a synergistic relationship.

Our integrative GARMi study illustrates how ethical considerations can be directly integrated into robot development through an embedded ethics and social science project. By synthesizing insights from ethical, legal, and social science perspectives, we identified vital concerns such as responsibility, accountability, liability, and transparency in the context of human-robot interactions. While our earlier work primarily focused on the philosophical conceptualization of responsibility (Tigard 2020, 2021), discussions around this study, informed by our legal experts, highlighted the more immediate concern of ‘accountability’ – especially given the potential risks of harm posed by a humanoid service robot. To attribute accountability in the event of an incident, it became clear that reconstructing events using stored data would be essential, leading our technical experts to propose the creation of a data recorder for the robot. Rather than looking at theoretical ethics to see how accountability should be operationalized, the social scientists led the joint conduct of stakeholder focus groups and came up with a more relational understanding of the concept. This realization led to the specification that a wide range of stakeholders, not just technical experts, should be able to comprehend the information contained in the data recorder. Based on these analyses and reflections, we collectively decided to design and implement a data recorder equipped with a visualization tool for incident investigation (Skerlj et al. 2023). This feature ensures accountability and transparency by applying stringent data security measures, minimizing the amount of data stored, providing a transparent and accurate account of the robotic system’s behavior and human-robot interaction, and visualizing the recorded data in an intuitive and immersive way. The visualization feature embodies a relational approach to accountability, facilitating accountability relationships between programmers, nurses, older users, and incident investigators. This feature allows non-expert users and other relevant stakeholders to participate in accountability processes that previously required technical experts as incident investigators. This study exemplifies the distributed and integrative nature of our normative reflections – progressing from conceptualization to empirical refinement and culminating in the development of norms and specific design requirements, each shaped by the contributions of different disciplines. It demonstrates how interdisciplinary collaboration can lead to concrete technical improvements that address ethical and societal issues.

Discussion: cross-disciplinary relationships in integrating ethics and social science

The experiences gained from our research underscore the crucial role of cross-disciplinary relationships for ‘integrating ethics’ (Mehnert, Fischer, and Ammon 2023) into robotics development. Our broad approach to ethics focuses not only on embedding

ethical considerations and social sciences into technological practices but also emphasizes the integration of diverse social scientific and ethics perspectives to ensure the responsible development of new technologies. By fostering collaborations among researchers from different fields and taking an empirical, bottom-up approach to researching issues from within development practice, we can jointly identify and address the potential harms and benefits of healthcare robots for groups and individuals, as well as their implications for accountability. We deem the question of whose input shapes the development of robotic applications an important ethical question in itself. Our embedded ethics and social science approach combines various disciplinary sensibilities and methods, avoiding a division between ethical and social dimensions. Through the collaborative activities described above, we have experienced shifts in identity, perspective, and skill development, enabling us to tackle ethical, social, and legal issues and jointly shape the research and development of robotics applications, as exemplified by our GARMI data recorder (Table 1).

Our collaborative relationships enabled disciplinary boundary-crossing that stood to challenge our respective professional identities. As Fisher (2019) has argued, integrative work disrupts what Nydal (2015, 21) has called ‘the modern normative division of labor

Table 1. Lessons learned for integrating ethics, social science, and law with technological research and development.

Theme	Lessons learned	Example activities
Building workable relationships in modest experimental co-laborations	<ul style="list-style-type: none"> • Engaging in short-term, smaller-scale co-laborations can foster mutual understanding, trust, and perspective shifts • Embracing an openness to serendipitous interactions and experimentation can yield unforeseen research opportunities • Modest experimental co-laborations can build foundations for longer-term strategic collaborations 	<ul style="list-style-type: none"> • automatica booth • Project Week co-teaching
Engaging knowledge holders in the application domain	<ul style="list-style-type: none"> • To ensure contextual relevance, team members from all disciplines should understand the specificities of the project’s application domains • Incorporating a multiplicity of approaches ensures a comprehensive perspective • When technoscientific projects have narrow approaches to stakeholder engagement, integrative initiatives can introduce more participatory approaches that engage stakeholder expertise 	<ul style="list-style-type: none"> • Stakeholder interviews • Focus group insights • Internships • LEGO® Serious Play® Workshop
Finding a focus point for collaborative research	<ul style="list-style-type: none"> • Smooth integration requires openly and flexibly shifting between modes of integration • Encouraging openness and flexibility among all parties involved, allowing approaches to be shaped collaboratively • While challenging, transcending disciplinary divisions of labor can be achieved by deeply and actively engaging with each other’s methods 	<ul style="list-style-type: none"> • GARMI study: designing & conducting focus groups together

affecting professional identities across sectors'. Our boundary-crossing activities of collaboratively designing focus groups and joining each other's events as co-exhibitors have expanded our horizons beyond traditional divisions of labor. It made us realize that all of us have been thinking hard about robots in society – even if often in very different reflexive ways – so that, consequently, our roles and respective expected contributions were not predetermined at the start and had to be figured out along the way. We found a collaborative flow where the socio-technical analyses and normative reflections were distributed across our different disciplinary directions, as described with the example of the GARMI data recorder.

Such experiences of socio-technical collaboration can add an identification with interdisciplinarity and integration. While most of us like to embrace this aspect into our professional identities and practice, there are certain hurdles that particularly junior researchers face. These concern the disciplinary requirements inherent in advancing research careers. While we have described many of our integrative engagements as 'small collaborations,' they nonetheless took considerable effort and were progressively difficult to take on as we advanced in our PhDs. We increasingly felt the need to focus on developing the subject-specific knowledge and skills expected of us to earn our doctoral degrees. Integrative work, it seems, remains an add-on that has to come on top of what is expected from a doctoral candidate in terms of qualification within their discipline and is, in and of itself, not always adequately recognized or rewarded within academia. While some of us have found solidarity in commiserating over these struggles, it remains a burden. This points to the need for new evaluation and career structures within academia (Fochler, Felt, and Müller 2016; Müller and de Rijcke 2017) that support socio-technical integration, which would allow researchers to cultivate integrative expertise.

Indeed, we have experienced our sustained socio-technical collaboration as a tacit skill-learning experience. One can hear and read about socio-technical collaborations and how to best carry out such projects, but for us, conducting these collaborations in reality brought forth a new sense of how to communicate and connect with experts across fields and how to assist and learn from others. One robotics researcher on our team understood this in terms of skill development. They emphasized that this collaboration necessitated that they develop the skill of expressing their thinking and explaining their research in ways that research partners outside their field would understand. Thus, we jointly developed the interactional expertise (Collins 2004) that enables integration.

Following Fisher (2007), we interpret this learning of interactional expertise as a form of capacity-building, which has often been emphasized as a desired outcome in the discourse of socio-technical integration (Fisher 2007, 2019; Fisher et al. 2015; Smolka and Bösch 2023). However, contrary to this discourse, which has largely used the term capacity to refer to the capacity of technoscientists specifically (Fisher, Mahajan, and Mitcham 2006; Fisher 2007), we look at capacities more symmetrically, considering the development of the capacities of our robotics researchers, STS scholars, ethicists, and legal scholars alike.

Therefore, our understanding of 'integrating ethics' includes not only influencing the design and development of technologies but also reciprocally adapting our own normative and epistemic approaches through disciplinary boundary-crossing. When ethics, social science, law, and technology are integrated with each other, all parties need openness and flexibility to shape their approaches throughout the collaborative process. We

have been simultaneously building and augmenting our capacities and those of our host initiative. We have, for example, given regular presentations at the Geriatrics Initiative's plenary meetings, adding an ethics and social science angle to the discussions; influenced their efforts in stakeholder involvement; and introduced them to a range of qualitative research methods and practices. These experiences improved their decision-making regarding study design and influenced how the Geriatrics Initiative integrates societal dimensions into their research, ultimately shaping the design of their robots. These effects were particularly pronounced among the technical researchers who were direct team members within the Responsible Robotics project. These researchers, as well as the legal scholars on our team, received training and were directly involved in focus group research, deepening their understanding of stakeholder engagement formats, which led them to embrace greater openness and consideration of stakeholder concerns and values. These experiences provide tentative evidence that training scholars in methods from another discipline can lead to a shift in their attentiveness, an option currently understudied in collaborative socio-technical integration.

Cross-disciplinary efforts have, in turn, helped our social science, ethics, and legal researchers develop a sensitivity and ability to make our insights accessible to technical communities. As an example, some on our team have targeted more technical journals with our publications and conferences, where we gave an introduction to embedded ethics and social science at a robotics conference (Breuer and Righetti 2023), proposed scenario-based focus groups as a method for human-robot interaction (HRI) research (Braun et al. 2022a), and illustrated the conceptual utility of 'engineers' imaginaries' in human-computer interaction (HCI) research (Breuer et al. 2023).

Beyond that, our non-technical team members have gained reflexive insights that we are taking back into our home disciplines. Notably, an insight specific to embeddedness with robotics and AI research is that this field articulates itself vis-à-vis the particular social and professional world it develops technology for – healthcare, in our case. It is therefore paramount for integrative researchers to take into account this additional professional sphere and its practices. This stands in contrast to science and society research that mainly enacts society as society at large, for example, in the case of genomics (Hilgartner, Prainsack, and Benjamin Hurlbut 2017), where ethicists and social scientists often are cast into the role of researchers and representatives of the public. By contrast, being embedded in a healthcare robotics and AI initiative necessitated researching the intricacies of the healthcare domain specifically. Domain-specific knowledge thus plays a central role in applied robotics/AI and socio-technical integration research alike.

Conclusions

Adding to a growing body of approaches aimed at responsible governance of robotics and AI (e.g. Wiesmüller et al. 2023; Stahl 2022; Wallach and Marchant 2019), we have shared practical reflections on the embedded ethics and social science approach (McLennan et al. 2020; Breuer et al. 2023). We highlighted the importance of establishing trusting peer-to-peer relationships that enable an integrative, interdisciplinary research approach. In the project we reported on, this approach facilitated mutual learning among experts from STS, ethics, law, and robotics, who stepped beyond their established disciplinary comfort zones to deeply engage with and acknowledge each other's

perspectives, transcending seemingly self-evident disciplinary boundaries. The reflexive capacities built through this mutual learning are crucial for addressing social, ethical, and legal aspects throughout the development process and for shaping technology design. These efforts, moreover, need to involve engaging the expertise of practitioners within the application domain of the technology, such as healthcare professionals. Integrative researchers need to understand not only the technical field in which they are embedded but also other highly specialized professional domains and their practices.

As a case study of embedded ethics and social science, our project was characterized by a wide range of engaged expertises, high embeddedness, open experimentation, and boundary-crossing activities. Through sustained collaboration, researchers from engineering, ethics, law, and STS can cultivate trusting relationships that foster synergistic peer-to-peer interactions. Whether in small co-laborative moments, engagements with additional stakeholder expertise, or in the co-design of more extensive research studies, collaborating researchers from different fields often have different goals and interests. However, if we still find ways of working together that are mutually beneficial, collaborative efforts yield unforeseen opportunities for data collection, reflexivity, and perspective shifts that turn these differences into something constructive. The trust and mutual understanding engendered in relationships cultivated over a longer time and in an experimental way allows researchers to dynamically shift between different modes of integration, e.g. supporting each other's goals, challenging normative commitments, or criticizing or supporting particular ways of doing research. These relationships thus build the basis for mutual learning, where researchers gain reflexive and interactional capacities that can help them address societal dimensions of (socio)technical research collaboratively.

To foster and harness these relationships and capacities, we need to create an appropriately conducive environment. This environment must accommodate the particular temporal dynamics inherent to embedded interdisciplinary collaboration and adequately reward integrative work. Our project has been situated in a privileged institutional setting that promotes continuous collaboration. Yet questions about the acquisition of funding and making successful career moves still arise and create friction. Integrative projects can arrange themselves with temporary co-laborations, as illustrated by the early phases of our project, that serve to cultivate the mutual understanding and trust that then allows for larger, more integrated collaborations, such as our GARMI study (Skerlj et al. 2023). Funding mechanisms, career pathways, and institutional support structures must provide sufficient time to cultivate durable collaborative relationships. By acknowledging and rewarding the contributions of researchers engaged in embedded and integrative work, such structures would ensure that their capacities can be effectively engaged to promote responsible research practices.

Note

1. Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 laying down harmonised rules on artificial intelligence and amending Regulations (EC) No 300/2008, (EU) No 167/2013, (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1139 and (EU) 2019/2144 and Directives 2014/90/EU, (EU) 2016/797 and (EU) 2020/1828 (Artificial Intelligence Act), OJ L 2024/1689, 1.

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