



UNIVERSIDADE FEDERAL DO ESTADO DO RIO DE JANEIRO
CENTRO DE CIÊNCIAS EXATAS E TECNOLOGIA
PROGRAMA DE PÓS-GRADUAÇÃO EM INFORMÁTICA

ENTANGLEMENT THEORIES AND SPECULATIVE DESIGN
IN THE CO-CONSTITUTION OF SOCIOTECHNICAL REALITIES

Marcelo Soares Loutfi

Advisor

Sean Wolfgang Matsui Siqueira

RIO DE JANEIRO, RJ - BRAZIL
OCTOBER 2025

ENTANGLEMENT THEORIES AND SPECULATIVE DESIGN
IN THE CO-CONSTITUTION OF SOCIOTECHNICAL REALITIES

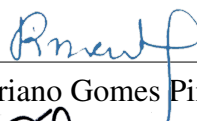
Marcelo Soares Loutfi

DOCTORAL DISSERTATION SUBMITTED AS A PARTIAL REQUIREMENT
FOR THE DEGREE OF DOCTOR IN INFORMATICS AT THE GRADUATE
PROGRAM IN INFORMATICS OF THE FEDERAL UNIVERSITY OF THE STATE
OF RIO DE JANEIRO (UNIRIO). APPROVED BY THE EXAMINING COMMITTEE
BELOW.

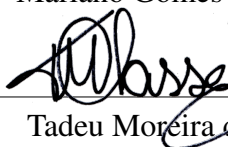
Aprovado por:



Sean Wolfgang Matsui Siqueira, D.Sc. - UNIRIO



Mariano Gomes Pimentel, D.Sc. - UNIRIO



Tadeu Moreira de Classe, D.Sc. - UNIRIO



Adriana Santarosa Vivacqua, D.Sc. - UFRJ



Renata Mendes de Araujo, D.Sc. - Mackenzie/USP



Roberto Pereira, D.Sc. - UFPR

RIO DE JANEIRO, RJ - BRAZIL
OCTOBER 2025

Cataloging data prepared by the author

Loutfi, Marcelo Soares.
F383 Entanglement Theories and Speculative Design in the Co-Constitution of Sociotechnical
Realities / Marcelo Soares Loutfi, 2025.
199p.

Advisor: Sean Wolfgang Matsui Siqueira
Doctoral Dissertation - Universidade Federal do Estado do Rio de Janeiro, Rio de Janeiro,
Programa de Pós-Graduação em Informática, 2025.

1. Information Systems 2. Human-Computer Interaction 3. Actor–Network Theory 4.
Speculative Realism 5. Agential Realism 6. Postphenomenology I. Siqueira, Sean Wolfgang Matsui,
advisor. II. Entanglement Theories and Speculative Design in the Co-Constitution of Sociotechnical
Realities

*I've seen things you people wouldn't
believe.*

Film: Blade Runner (1982)

Acknowledgments

São tantas as pessoas que eu gostaria de agradecer que foi difícil condensar tudo em uma página. Começo pela minha família: irmãos, sobrinhos, cunhados, pai e mãe. Minhas irmãs Leila e Vá vieram de outras cidades para me visitar em um momento delicado, gestos de carinho que nunca esquecerei. Vá, a irmã artista, me apoiou no design das ferramentas, criando inclusive a nova identidade visual do SaLT. Leila, minha irmã gratiluz, ao lado do marido Hipólito e do meu sobrinho Matheus, me acolheu em sua casa na reta final da tese, ajudando-me a recarregar as energias para chegar até aqui. Rico, Khau, Karina e Dê estiveram sempre por perto, cada um ao seu modo. Rico, com sua visão de mundo profunda, ajudou a clarear pensamentos obtusos. Karina, com seu pragmatismo, me ajudou a simplificar os problemas complexos da vida cotidiana. Khau, a chefe da firma, me amparou com sua espiritualidade e intuição afiada nos momentos em que mais precisei. E Dê, com sua habilidade de manter todos unidos no WhatsApp, fez com que eu permanecesse próximo dos sobrinhos e cunhados, mesmo à distância. Também agradeço ao Ivan, meu irmão gêmeo, por ter me amparado, cuidando da minha cachorrinha Peggy quando precisei e, também, a todos que cuidaram dela e das minhas plantinhas durante as viagens para simpósios. São muitos, e seria impossível citar todos, mas deixo aqui meu sincero reconhecimento. A Peggy, aliás, agradece também.

À Eugênia, que parceira maravilhosa! Esteve incondicionalmente ao meu lado em cada vitória e tropeço, oferecendo o respiro de que eu precisava. Sua leveza foi o impulso silencioso que me ajudou a seguir em frente. Ao meu pai, que onde quer que esteja provavelmente diria “não fez mais que sua obrigação”, mas que no fundo sei que se orgulha e deve contar aos amigos no céu as conquistas dos filhos. E principalmente à minha mãe, agradeço pela força e serenidade com que mantém todos unidos, o verdadeiro alicerce da família.

Aos amigos Celso, Daniel, Geo, Ingrid, Marie, Reinaldo, Nathielly, Rita, Tiago, Eduardo, Mari, Charles, Carla, Eric, Paula, Maurício, Roberto e tantos outros, meu sincero agradecimento por terem feito parte dessa longa caminhada de quase seis anos, cada um ao seu tempo.

E sim, agradeço também a alguns não humanos que me acompanharam nessa jornada. À Peggy, minha cachorrinha e fiel bola Wilson (pegaram a referência?), com quem dialoguei pensamentos e ideias durante a pandemia e que, de algum modo, parece me conhecer como ninguém. Ao Tufic, o filhote serelepe da Peggy, que transforma lixo em arte com suas instalações improvisadas de papel higiênico que deixariam Vik Muniz com inveja. À Emma, a gatinha da Eugênia que aquece qualquer coração. Agradeço ainda à parafernália tecnológica, o computador, o notebook, o tablet, o celular e até o espírito maquínico da IA. Também agradeço a uma consciência cósmica, que ainda não sei como nomeá-la, mas que se revelou em vários momentos, lembrando-me de que existem forças sutis guiando meu caminho.

Um salve ao grupo SaLT (Social and Learning Technologies), que se tornou um verdadeiro coletivo de pensamento. Agradeço também à UNIRIO e aos professores que se tornaram amigos e ao Programa de Pós-Graduação em Informática (PPGI). À CAPES, pelo apoio financeiro que sustentou esta pesquisa. Aos membros da banca, pela leitura atenta e pelas contribuições generosas, deixo meu sincero reconhecimento.

Um agradecimento especial ao professor Sean Siqueira. Nunca conheci alguém tão atento, generoso e genuinamente empático com seus orientandos. Ao invés de simplesmente revelar o caminho de antemão, ele nos conduz a uma travessia repleta de descobertas, reflexões e momentos de autoconhecimento que transcendem os limites da pesquisa e se tornam lições para toda a vida.

Research Itinerary

I believe that the personal trajectory culminating in this dissertation began long before its formal starting point. It traces back more than twenty years, when I worked simultaneously in the software industry and as a lecturer in higher education. Throughout this period, I experienced and observed two movements that shaped my understanding of the relationship between technology, professional practice, and education.

First Movement: Ageism in Computing

The first movement emerged during my work as a Systems Analyst and Software Developer. I realized that, as we grow older, the accumulation of experience in the field does not carry the same value attributed to it in professions such as Medicine or Law. There is a form of structural ageism in Computing: by the age of forty, professionals are often already considered “old”.

The industry tends to celebrate the energy of young programmers (those willing to endure long working hours in exchange for a slice of pizza and a soda) while the expertise accumulated over the years is frequently underestimated or ignored. This culture that glorifies novelty, the “trendy” programming language, and the “cutting-edge” technology began to unsettle me deeply. I started to ask myself: why are older professionals so readily discarded? Why is technical proficiency so disproportionately valued? And what explains this almost compulsive pursuit of technological novelty?

Second Movement: The Devaluation of Education

In the educational sphere, I encountered a phenomenon that was perhaps even more concerning. Computing education in Brazil, particularly within private universities, had been undergoing a progressive fragmentation marked by increasingly disconnected courses, reduced teaching hours, and a growing technicist and market-oriented orientation. Many students aspired to become specialists in narrow subfields, such as databases, cloud computing, or front-end development, yet lacked a solid conceptual foundation and the analytical capacity needed to understand the social and ethical role of technology.

I recall an experience in 2018 when I proposed a simple exercise: reflecting on the role of social media in elections. Not a single student grasped the purpose of the activity. Although the Ministry of Education mandates content on Computing ethics, the topic is often addressed superficially in practice. Many students (most of whom come from socioeconomically vulnerable backgrounds) prioritized technical training as a means of social mobility, which is entirely understandable given the market’s demand for strictly technical competencies.

As working conditions in private institutions deteriorated, I realized it was time for a new movement: beginning the doctoral program. My goal was to rediscover the meaning of critical education in technology and to contribute, from within a public university, to rethinking both the teaching and the social role of Computing.

Encountering Sociotechnical Networks

I began the doctoral program in 2020, one month before the COVID-19 pandemic spread across the globe. In that context, I started studying the more troubling dimensions of social networks and noticed something unsettling: the “truth” circulating on these platforms seemed to overshadow objective truth itself. What was real became blurred by what was shared, liked, or algorithmically amplified.

I later came to understand COVID-19 not merely as a biological virus but as a sociotechnical agent. It shaped behaviors, transformed forms of social interaction, accelerated the emergence of new technologies, consolidated remote work and education, produced novel discourses around vaccines, and reconfigured our perception of reality. Beyond that, the virus gave rise to competing narratives: Was it engineered by China? Was it a media invention? A harbinger of the end times? These narratives revealed that the pandemic was far more than a biological event; it was a technocultural phenomenon in which science, politics, technology, and belief became entangled in the construction of the real.

This realization inspired me to write the article “CovidTrends: Identifying Behaviors during the COVID-19 Pandemic - An Analysis based on Google Trends and News”, presented at Brazilian Symposium on Information Systems (SBSI 2021), in which I investigated how search data and news coverage reflected shifts in collective behavior during that period.

In parallel, I deepened my study of addictive behaviors, which intensified during the lockdown. I developed psychometric scales and published the article “Addicted to Social Media? An Adaptation of the Internet Addiction Test (IAT) for Problematic Social Media Use”¹ in the journal Gestao.org. The article received an award in recognition of its scientific contribution. However, I soon realized that something extended beyond the individual dimension: addiction was not merely a behavioral issue but a carefully engineered phenomenon. There was an underlying intentionality embedded in technical structures designed to capture attention and induce dependency. These systems were shaped by multiple hands, not all of them necessarily human.

This realization led me to seek theoretical frameworks capable of explaining the complexity of relationships between subjects and technological artifacts. Along this path, I encountered Actor-Network Theory (ANT) and its main authors: Bruno Latour, John Law, Madeleine Akrich, Michel Callon, and Tommaso Venturini. I immersed myself in their work, attended courses on Actor-Network Theory and Cartography of Controversies, watched lectures, and explored complementary philosophical

¹Original title of the article: “Viciado em Mídias Sociais? Uma Adaptação do Internet Addiction Test (IAT) para Uso Problemático de Mídia Social”

perspectives that resonated with ANT.

Even so, the predominantly descriptive character of the approach left me somewhat unsettled. Understanding without intervening never seemed sufficient to me. This impulse marked a turning point in my trajectory: the desire to move beyond description and enter the realm of transformation and possibilities for action.

Encountering the Entanglement Theories

In search of more action-oriented approaches, I turned to Gilbert Simondon and, subsequently, to the so-called neomaterialist thinkers. In the midst of the pandemic, between late-night readings and long conversations with friends and with my little dog, I immersed myself in Speculative Realism, particularly in the works of Graham Harman, Quentin Meillassoux, and Ian Bogost. From there, I broadened my horizon to other strands that challenge the role of technology, engaging with authors such as Shoshana Zuboff, Donna Haraway, Karen Barad, and Manuel DeLanda. Their reflections expanded my understanding of the agency of artifacts and the materiality of technological relations. Even so, I did not yet know exactly where these readings might lead me; I sensed only that they were bringing me closer to a new way of understanding the relations that weave the complexity of the world.

It was at the end of 2022, when I read Frauenberger's article on Entanglement HCI, which proposed a new paradigm of Human-Computer Interaction grounded in entanglement theories, that I finally sensed a point of convergence. For the first time, all those philosophical readings seemed to find a place within Computing. Despite the theoretical density, I recognized in that work a possibility to transform complex concepts into meaningful practices capable of engaging my colleagues and inspiring my students.

I did not yet know exactly how to situate those theories or how to translate them into something practical. I presented them several times to the Social and Learning Technologies (SaLT)² research group, attempting to explain their possible connections to Computing, but I soon realized that the philosophical vocabulary created barriers. The concepts were dense, abstract, and unfamiliar to our training. To be honest, I myself was not entirely certain about what I was saying. I was feeling my way through, trying to understand while also trying to make the ideas understandable. They seemed distant from the work of my colleagues, who developed their research on “search as learning” and related areas with remarkable expertise. I, supported unconditionally by my advisor, followed a solitary and uncertain path, searching for an appropriate tone to articulate philosophy and technology.

From Questions to Tools

In early 2023, I decided to simplify. I began organizing the discussions around three fundamental questions: Where are we? Where are we heading? Where do we want to

²SaLT website: [<https://salt.uniriotec.br/>](https://salt.uniriotec.br/)

go? Based on these questions, I developed my own way of translating philosophical concepts into vocabulary that was more accessible to the Computing field, using analogies, examples, and reflections connected to the practices of computing professionals, users, and educators. Over time, this dialogue began to flow more naturally.

I recall a striking moment during one of the SaLT group meetings. I walked into the laboratory and, with considerable conviction, stated: “The flat Earth exists.” My colleagues’ astonishment was immediate, until I explained that, from the perspective of speculative realism, the flat Earth exists as a concept. Although it does not correspond to empirical reality, it possesses existence in the realm of ideas and produces concrete effects in the world. Everything we project mentally exists in some way, and ignoring such phenomena also means ignoring the repercussions they have on everyday life. I was pleased to see that everyone understood the provocation and followed the reasoning, which revealed the importance of understanding how mental projections and technologies become entangled and generate phenomenological effects on how we perceive and act in the world.

The dissertation began to take shape in late 2022, when the first conceptual elements emerged from my initial engagement with Entanglement Theories, particularly informed by Frauenberger’s work. As these ideas gradually converged with my growing interest in Speculative Design, the structure of the thesis started to become clearer, and the foundations of the framework began to form. This trajectory was further consolidated in 2024, when I participated in a doctoral consortium and presented the work “Speculative Design and Entanglement Theories in Information Systems Design” during the ACM SIGCHI Symposium on Engineering Interactive Computing Systems (EICS 2024), held in Cagliari, Italy. At that time, I had already outlined a preliminary version of the framework and some of the tools that compose it.

I conducted several pilot workshops and eventually realized that the issue did not lie solely in the tools but in the very way we have been programmed to understand the world. Even when introduced to new methodologies and platforms, many participants continued to reproduce longstanding patterns of thought shaped by Cartesianism, reductionism, and positivism. I then understood that providing instruments was not enough; it was necessary to create spaces that fostered critical reflection and openness to other ways of thinking, feeling, and designing.

It was from this realization that the framework assumed its current form, by integrating a philosophical intent grounded in post-anthropocentric principles derived from the Entanglement Theories. Although these theories are dense and complex, the principles formulated from them translate their foundations into language that is more accessible and applicable. This perspective came to guide both the design of the framework and its tools and the facilitation of the speculative design workshops.

Consolidation of the Research and Scientific Dissemination

Beginning in 2024, my work started to gain greater visibility within the scientific community, with the publication and presentation of papers at national and international

conferences in the fields of Human-Computer Interaction and Information Systems.

Among the full papers, the following stand out:

- (Loutfi; Siqueira, 2024): “Speculative Design in a Graduate Program in Informatics: Students’ Perception and Practical Application - A Novel Approach for Supporting Information Systems Education”, presented at the Brazilian Symposium on Information Systems (SBSI 2024).
- (Loutfi *et al.*, 2025a): “Explorando Futuros Tecnológicos em Contexto: Um Relato de Experiência com Design Especulativo e IA Generativa na Graduação”³, presented at IHC 2025.
- (Loutfi *et al.*, 2025b): “Teorias do Emaranhado e Design Especulativo na Computação: Mapeamento Sistemático de Literatura e Implicações para a Interação Humano-Computador”⁴, presented at the Brazilian Symposium on Human Factors in Computing Systems (IHC 2025).
- (Loutfi *et al.*, 2025): “Students’ Perceptions of Speculative Design with Generative AI in Creating Futuristic Narratives - An Interdisciplinary Study with Undergraduate Students from Diverse Fields”, presented at SBSI 2025.

In addition to these, I produced short papers:

- “Speculative Design and Entanglement Theories in Information Systems Design”, presented at the 16th ACM SIGCHI Symposium on Engineering Interactive Computing Systems (EICS 2024) in Cagliari, Italy.
- “Enfrentando os Desafios do Tecnicismo Reducionista na Computação”⁵, presented at the event Grand Challenges of Computing Education in Brazil 2025-2035 (GDEC 2024).
- “Futuros Desejáveis com Design Especulativo: Um Novo Olhar para os Sistemas de Informação”⁶, presented at Grand Research Challenges in Information Systems in Brazil (GranDSI-BR 2026-2036).
- “Speculative Design as a Post-Phenomenological Practice”, presented at the workshop: Phenomenological Concepts and Methods for HCI Research, during INTERACT 2025.

My scholarly production also extended to the publication of book chapters, both resulting from practical teaching and research experiences with Speculative Design:

³English title: “Exploring Technological Futures in Context: An Experience Report with Speculative Design and Generative AI in Undergraduate Education”

⁴English title: “Entanglement Theories and Speculative Design in Computing: A Systematic Literature Mapping and Implications for Human-Computer Interaction”

⁵English title: “Facing the Challenges of Reductionist Technicism in Computing”

⁶English title: “Desirable Futures with Speculative Design: A New Perspective for Information Systems”

- (Loutfi *et al.*, 2024): “Design Especulativo: Construindo Pontes entre Tecnologia, Ética e Inclusão Social”, in “Minicursos do IHC 2024”⁷ (SBC, 2025), edited by Claiton Corrêa and Saul Delabrida, pp. 18-38.
- (Loutfi *et al.*, 2024): “Cartas de Mediação Tecnológica”⁸, in “Práticas de IHC em Sala de Aula: Ações Extensionistas em Pauta” (SBC, 2024), edited by Amanda Meincke Melo and Thiago Adriano Coleti, pp. 7-12.

Currently, I have two journal articles under review in high-impact venues, in addition to a workshop titled “Sistemas de Informação além do Sociotécnico: Explorando o Entrelaçamento entre IA e Humanos com Design Especulativo”⁹, which has been accepted for SBSI 2026.

The Future Begins Here

I now understand that the concerns that have driven me from the beginning, such as ageism in Computing, the devaluation of critical education, and the technicism that impoverishes our worldview, were symptoms of something deeper: the need to rethink how Computing relates to the human, the non-human, and knowledge itself. This journey ultimately brought me back to my origins, now with the perspective of someone who recognizes that technology, education, and life must serve a greater purpose.

Over time, I realized that Speculative Design, when guided by post-anthropocentric principles emerging from Entanglement Theories, ceased to be merely a research approach and became a way of being in the world. It became a way of living that looks toward the future without losing sight of the present, recognizing in the present the space where desirable futures begin to take shape. This perspective permeates everything I do: scientific projects, personal plans, affective relationships, and collective experiences.

Speculation has become a gesture of care and imagination, a way of thinking with the heart and acting with responsibility. Designing, for me, has become an act of attentiveness to relationships, consequences, and the networks that emerge within the entanglement we inhabit. I came to understand that to speculate is not to escape reality but to expand it and co-create it, facing the present with the courage of someone willing to envision the possible, the desirable, and even the undesirable before they become real.

⁷English title of the book chapter: “Speculative Design: Building Bridges between Technology, Ethics, and Social Inclusion”

⁸English title of the book chapter: “Technological Mediation Cards”

⁹English title of the workshop: “Information Systems Beyond the Sociotechnical: Exploring the Entanglement between AI and Humans with Speculative Design”

LOUTFI, MARCELO SOARES **Teorias do Emaranhado e Design Especulativo na Co-Constituição de Realidades Sociotécnicas**. UNIRIO, 2025. 199 páginas. Qualificação/Dissertação/Tese de Mestrado/Doutorado. Programa de Pós-Graduação em Informática, UNIRIO.

RESUMO

Esta tese propõe uma abordagem teórico-metodológica para o design de tecnologias, fundamentada na integração entre as Teorias do Emaranhado e o Design Especulativo. Partindo do reconhecimento de que as realidades sociotécnicas são constituídas por relações dinâmicas e híbridas entre humanos e não-humanos, este trabalho questiona abordagens tradicionais de design que privilegiam a centralidade humana, a previsibilidade e o controle técnico. As Teorias do Emaranhado incluem a Teoria Ator-Rede (TAR), o Realismo Especulativo, o Realismo Agencial e a Pós-Fenomenologia. Essas teorias fornecem a base para compreender os processos de co-constituição de ecossistemas sociotécnicos, nos quais tecnologias não são apenas ferramentas, mas participantes ativos na produção de realidades e futuros. A tese desenvolve o Sociotechnical Entanglement Framework (SEF), um arcabouço que traduz os princípios dessas teorias em práticas de Design Especulativo. Além disso, são apresentadas ferramentas de apoio, como a Lousa Sociotécnica, as Cartas de Mediação Tecnológica e as Rodas de Implicações Sociotécnicas e de Possibilidades, que operam como dispositivos de reflexão, intervenção e fabulação. Os resultados empíricos incluem a aplicação deste framework (com as ferramentas) em oficinas de design especulativo, revelando seu potencial para fomentar práticas de design mais reflexivas, éticas e sensíveis às complexidades das realidades sociotécnicas. A abordagem proposta amplia a capacidade dos profissionais de tecnologia de pensar além dos modelos centrados no humano, promovendo a imaginação crítica e o desenvolvimento de soluções que reconhecem a agência distribuída entre humanos e não-humanos.

Palavras-chave: Design Especulativo, Teorias do Emaranhado, Pós-Humanismo, Transhumanismo, Pós-Antropocentrismo, Ecossistemas Sociotécnicos, Teoria Ator-Rede, Pós-Fenomenologia, Teoria da Mediação Tecnológica, Realismo Agencial, Realismo Especulativo, Ontologia Orientada a Objetos.

ABSTRACT

This thesis proposes a theoretical-methodological approach to technology design, grounded in the integration between Entanglement Theories and Speculative Design. Starting from the recognition that sociotechnical realities are constituted by dynamic and hybrid relationships between humans and non-humans, this work questions traditional design approaches that privilege human centrality, predictability, and technical control. The Entanglement Theories include Actor-Network Theory (ANT), Speculative Realism, Agential Realism, and Postphenomenology. These theories provide the basis for understanding the processes of co-constitution of sociotechnical ecosystems, in which technologies are not merely tools but active participants in the production of realities and futures. The thesis develops the Sociotechnical Entanglement Framework (SEF), an architecture that translates the principles of these theories into Speculative Design practices. In addition, it presents support tools such as the Sociotechnical Whiteboard, the Technological Mediation Cards, and the Sociotechnical and Possibility Wheels, which operate as devices for reflection, intervention, and fabulation. The empirical results include the application of this framework (with the tools) in speculative design workshops, revealing its potential to foster more reflective, ethical, and sensitive design practices toward the complexities of sociotechnical realities. The proposed approach enhances the ability of technology professionals to think beyond human-centered models, promoting critical imagination and the development of solutions that acknowledge the distributed agency between humans and non-humans.

Keywords: Speculative Design, Entanglement Theories, Posthumanism, Transhumanism, Post-Anthropocentrism, Sociotechnical Ecosystems, Actor-Network Theory, Postphenomenology, Theory of Technological Mediation, Agential Realism, Speculative Realism, Object-Oriented Ontology.

Contents

1 Introduction	1
1.1 Contextualization	1
1.1.1 The Paradigm of the Nature-Culture Bifurcation	2
1.1.2 Critique of Modern Scientific Thought	3
1.2 Motivation	5
1.3 Research Problem	7
1.4 Research Objectives	8
1.5 Alignment of the Research with the Major Themes in IS, HCI, and Computing Education	9
1.6 Alignment of the Research with the Sustainable Development Goals . . .	10
1.7 Research Relevance	12
1.8 Methodological Organization of the Dissertation	13
2 Entanglement Theories and Speculative Design	16
2.1 Contextualization	16
2.2 Actor-Network Theory	18
2.2.1 Sources of Uncertainty in ANT	18
2.2.2 Black Boxes	20
2.2.3 Double Click	21
2.3 Postphenomenology and the Theory of Technological Mediation	21
2.3.1 Types of Technological Mediation	23
2.3.2 Symbolic Notation of Technological Mediation	24
2.4 Speculative Realism	25
2.4.1 Correlationism	26
2.4.2 Object-Oriented Ontology	27
2.4.3 Ontography	28

2.5 Agential Realism	29
2.5.1 Materiality	29
2.5.2 Diffractive Method	30
2.5.3 Intra-Action	31
2.5.4 Agential Cuts and Apparatuses	31
2.5.5 Ethics and Responsibility	32
2.6 Speculative Design	32
2.6.1 Future-Oriented Design	32
2.6.2 Theoretical Perspectives in Speculative Design	34
2.6.3 Tension Patterns in Speculative Design	35
2.6.4 Speculative Design Tools	37
2.6.4.1 Standalone Toolkits	38
2.6.4.2 Toolkits for Frameworks and Methodologies	38
2.7 Final Considerations of the Chapter	39
3 Literature Review	40
3.1 Contextualization	40
3.2 Bibliometric Analysis	41
3.2.1 Research Method	42
3.2.2 Data Analysis	42
3.2.3 Results and Discussion of the Bibliometric Analysis	43
3.2.3.1 Overview of Research on Entanglement Theories in IS	43
3.2.3.2 Key References and Their Articulation with Authors and Themes	44
3.2.3.3 Thematic Evolution and Emerging Theoretical Approaches	46
3.3 Systematic Literature Mapping	49
3.3.1 Research Method	49
3.3.2 Data Analysis	49
3.3.3 Results and Discussion of the Systematic Literature Mapping	49
3.3.3.1 Synthesis of Related Work	50

3.3.3.2 Gaps and Trends in the Articulation between Entanglement Theories and Speculative Design	51
3.3.4 Conclusion of the Systematic Literature Mapping	53
3.4 Final Considerations of the Chapter	55
4 The Proposal of the Sociotechnical Entanglement Framework for a Post-Anthropocentric Design	56
4.1 Contextualization	56
4.2 Comparative Analysis of Entanglement Theories	57
4.3 Redefining Sociotechnical Networks from an Entanglement Perspective	57
4.4 Formulation of the Post-Anthropocentric Principles	60
4.4.1 Non-Human Actors Must Be Made Visible	60
4.4.2 Human Agency Is Not Autonomous but Mediated	61
4.4.3 Reality Is Relational and Irreducible to Totality	62
4.4.4 We Must Speculate in the Face of Uncertainty	62
4.4.5 In Defense of a Cosmopolitics of Hybrids	63
4.4.6 Ethics and Responsibility Emerge within Sociotechnical Relations	64
4.5 Conception and Refinement of the Sociotechnical Entanglement Framework	64
4.6 Final Considerations of the Chapter	68
5 Sociotechnical Entanglement Toolkit	69
5.1 Contextualization	69
5.2 Sociotechnical Board: An Ontographic Mapping of Actants	69
5.3 Sociotechnical Implications Wheel: Recognizing Modes of Existence	71
5.4 Possibilities Wheel: Exploring the Tangibility of Futures	74
5.5 Technological Mediation Cards: Speculative Provocations Informed by Postphenomenology	75
5.6 Tools for Documentation, Data Collection, and Systematization	78
5.6.1 Support Notebook 1	78
5.6.2 Support Notebook 2	78

5.6.3	Support Notebook 3	79
5.6.4	Support Notebook 4	80
5.6.5	Support Notebook 5	81
5.6.6	Positioning the Sociotechnical Entanglement Toolkit within the SEF	82
5.7	Final Considerations of the Chapter	83
6	Methodological Procedures of the Participatory Speculative Design Workshop	84
6.1	The Entanglement Paradigm as a Research Orientation	84
6.2	Participatory Design	85
6.3	Participatory Speculative Design Workshops	86
6.4	Empirical Implementation of the SEF: Speculative Design Workshop at IHC 2024	87
6.4.1	Workshop Planning Protocol	87
6.4.2	Pre-Workshop Planning	88
6.4.2.1	Ethical Considerations	88
6.4.2.2	Participant Profile	88
6.4.2.3	Workshop Dissemination	89
6.4.2.4	Materials and Tools	89
6.4.3	Workshop Planning	90
6.4.3.1	Introduction and Concepts of Speculative Design	91
6.4.3.2	Stage 1: Topic Selection	91
6.4.3.3	Stage 2: Modeling the Sociotechnical Ecosystem	92
6.4.3.4	Stage 3: Sociotechnical and Possibilities Implications	92
6.4.3.5	Stage 4: Designing the Interventionist IT Solution	93
6.4.3.6	Stage 5: Future Narrative	94
6.4.3.7	Stage 6: Sharing Responsibilities	94
6.4.3.8	Stage 7: Presentation	95
6.4.3.9	Discussion and Closing	95
6.4.4	Workshop Execution	95

6.4.4.1 Workshop Participants and Activity Duration	95
6.4.4.2 Interaction with the Tools	96
6.4.4.3 Adjustments Made During the Workshop	98
6.4.4.4 Produced Material	98
6.5 Data Collection	99
6.6 Data Analysis	100
6.6.1 Content Analysis	100
6.6.2 Diffractive Analysis	101
6.7 Final Considerations of the Chapter	103
7 Future Scenarios and Technological Solutions Designed in the Workshop	104
7.1 Contextualization	104
7.2 Dating Sites and Platforms (Group 1)	104
7.2.1 Current Scenario and Future Implications	105
7.2.2 Speculation of the Technological Solution	106
7.2.3 Alignment with the Main Objectives	108
7.2.4 Futuristic Narrative and Shared Responsibilities	108
7.3 Streaming Platforms (Group 2)	110
7.3.1 Current Scenario and Future Implications	110
7.3.2 Speculation of the Technological Solution	112
7.3.3 Futuristic Narrative and Shared Responsibilities	112
7.4 Streaming Platforms (Group 3)	114
7.4.1 Current Scenario and Future Implications	114
7.4.2 Speculation of the Technological Solution	115
7.4.3 Alignment with the Main Objectives	116
7.4.4 Futuristic Narrative and Shared Responsibilities	117
7.5 Betting Platforms - BETs (Group 4)	118
7.5.1 Current Scenario and Future Implications	119
7.5.2 Speculation of the Technological Solution	120

7.5.3	Alignment with the Main Objectives	121
7.5.4	Futuristic Narrative and Distribution of Responsibilities	121
7.6	Final Considerations of the Chapter	123
8	Results	124
8.1	Exploration of the Sociotechnical Landscape	124
8.2	Post-Anthropocentric Perspectives	126
8.2.1	Principle P1: Representativity of Actants	126
8.2.2	Principle P2: Artifacts as Mediators of Human Action	127
8.2.3	Principle P3: Relational and Non-totalizing Reality	128
8.2.4	Principle P4: Speculation in the Face of Uncertainty	129
8.2.5	Principle P5: Cosmopolitics in Support of Hybrid Constitution	129
8.2.6	Principle P6: Sociotechnical Relations Producing Design with Shared Responsibility	130
8.3	Participant Engagement	131
8.4	Final Considerations of the Chapter	131
9	Discussion	133
9.1	Alignment with Post-Anthropocentric Principles	133
9.1.1	Impact of the SEF on the Visibility of Non-Human Actors	133
9.1.2	The Emergence of Human Agency as Mediated	135
9.1.3	The Incompleteness of Design in the Face of a Complex World	135
9.1.4	The Power of Collective Sensemaking Practices	136
9.1.5	Activating the Cosmopolitics of Hybrids	137
9.1.6	Ethics and the Sharing of Responsibility	138
9.2	Entanglements among Philosophical Currents	139
9.2.1	Actor-Network Theory and Speculative Realism in the Mapping of Sociotechnical Ecosystems	139
9.2.2	Speculative Realism and Futures Design	141
9.2.3	Postphenomenology as an Extension of Agential Realism in the Evaluation of the Human-Technology-World Relation	142

9.3 Interference Patterns in a Diffractive Method	142
9.3.1 Interference Pattern: Evaluative Intra-Actions and the Reconfiguration of the Analytical Gaze	142
9.3.2 Interference Pattern: The Light That Goes Out and the Phenomenon That Lights Up	143
9.3.3 Interference Pattern: Cognitive Reconfigurations with GenAI	144
9.4 Final Considerations of the Chapter	144
10 Conclusion	147
10.1 Theoretical and Methodological Contributions	147
10.2 Educational Contribution	149
10.3 Technical Contribution	149
10.4 Practical Contribution	150
10.5 Threats to Validity	150
10.6 Future Work	151
References	152
A Detailed Bibliometric Analysis	171
A.1 Method	171
A.1.1 Language and Search String	171
A.1.2 Inclusion and Exclusion Criteria	173
A.1.3 Selection of Scientific Databases	173
A.1.4 Selection Procedures	174
A.1.5 Data Analysis	175
A.1.5.1 Annual Article Production	175
A.1.5.2 Citation Analysis	176
A.1.5.3 Authorship Analysis	176
A.1.5.4 Reference Analysis	176
A.1.5.5 Thematic Analysis	176

A.2 Results and Discussion	177
A.2.1 Overview of Research on Entanglement Theories in IS	177
A.2.2 Evolution of Academic Impact	179
A.2.3 Production Dynamics and Collaboration Among Leading Authors	181
A.2.4 Key References and Their Articulation with Authors and Themes	183
A.2.5 Thematic Evolution and Emerging Theoretical Approaches	185
B R Script for Integrating Scopus and WoS Data in Biblioshiny	190
C Original Version of the Sociotechnical Board Data Count	191
D Original Version of Group 2's Sociotechnical Board	192
E Questionnaire administered to the participants of the workshop at IHC 2024	193

List of Figures

Figure 1: Modern separation between the poles of nature and culture.	3
Figure 2: Dissertation Structure	14
Figure 3: Systematization of the Theory of Technological Mediation (TTM).	22
Figure 4: Example of Correlationism.	26
Figure 5: Ontography of Relations among Actors, Objects, and Actions	28
Figure 6: Comparison between the Representationalist Model and Performativity	30
Figure 7: Interconnection among Design Approaches within a Future-Oriented Perspective	33
Figure 8: Stages of the literature review process.	40
Figure 9: Most Frequently Cited References by Leading Authors and the Most Prevalent Keywords	45
Figure 10: Keyword Co-occurrence Network	47
Figure 11: Trending Topics	48
Figure 12: Stages for constructing the SEF framework	57
Figure 13: Understanding sociotechnical networks through the lens of Entanglement Theories.	59
Figure 14: Diagram of the Three Fundamental Questions.	65
Figure 15: <i>Sociotechnical Entanglement Framework</i> (SEF).	67
Figure 16: Representations of the Sociotechnical Board: (1) digital version and (2) physical version.	70
Figure 17: Representations of the Sociotechnical Implications Wheel: (1) digital version and (2) physical version.	71
Figure 18: Representations of the Possibilities Wheel: (1) digital version and (2) physical version.	74
Figure 19: Cartas de Mediação Tecnológica.	76
Figure 20: Cyborg Card: front and back.	77

Figure 21: Notebook 1 with initial themes to activate speculation.	78
Figure 22: Notebook 2 used for organizing and classifying implications.	79
Figure 23: Notebook 3 for supporting reflections on technological mediations.	80
Figure 24: Notebook 4 as a tool for staging situated futuristic narratives.	81
Figure 25: Notebook 5 as support for diffractive practice and shared responsibility among actants.	82
Figure 26: Conceptual and Operational Placement of the SEF Toolkit.	83
Figure 27: Sequence of workshop activities.	90
Figure 28: Count of information from Group 3's Sociotechnical Board.	102
Figure 29: Speculative Scenario: Dating Applications in 2030 (Group 1).	105
Figure 30: Proposed Solution: Dating Applications in 2030 (Group 1).	107
Figure 31: Futuristic narrative (Group 1).	109
Figure 32: Speculative scenario: Streaming Platforms in 2030 (Group 2).	111
Figure 33: Proposed Solution: Streaming Platforms in 2030 (Group 2).	113
Figure 34: Futuristic narrative (Group 2).	113
Figure 35: Speculative scenario: Streaming Platforms in 2029 (Group 3).	115
Figure 36: Proposed Solution: Streaming Platforms in 2029 (Group 3).	116
Figure 37: Futuristic narrative (Group 3).	117
Figure 38: Speculative scenario: Betting Platforms — BETs (Group 4).	119
Figure 39: Proposed solution: Betting Platforms in 2026 (Group 4).	120
Figure 40: Futuristic narrative (Group 4).	122
Figure 41: Sociotechnical Board of Group 2 (Streaming Platforms).	140
Figure 42: Base Search String	172
Figure 43: Identification and selection process	174
Figure 44: Annual Production of Studies	178
Figure 45: Average Citations per Year Over Time	180
Figure 46: Publication Chronology of Leading Authors	182

Figure 47: Collaboration Network Among Authors	183
Figure 48: Most Cited References by Leading Authors and the Most Prevalent Keywords	184
Figure 49: Keyword Word Cloud	186
Figure 50: Keyword Co-occurrence Network	187
Figure 51: Trending Topics	188
Figure 52: R Code for Data Preparation in Bibliometric Analysis	190
Figure 53: Analytical Counting of the Information from Group 3's Sociotechnical Board (Original).	191
Figure 54: Sociotechnical Board of Group 2 (Original).	192

List of Tables

Table 1: Seminal Works and Key Contributions for Each Theory.	17
Table 2: Sources of Uncertainty in ANT.	18
Table 3: Verbeek's Types of Relations with Symbolic Representation.	23
Table 4: Tension Patterns in Speculative Design	35
Table 5: General Overview of the Bibliometric Data	43
Table 6: Most Frequently Cited External References in the Analyzed Documents	44
Table 7: Exploration of Entanglement Theories through Speculative Design	50
Table 8: Gaps and Trends in the Integration between Entanglement Theories and Speculative Design	52
Table 9: Challenges in Integrating Entanglement Theories and Speculative Design	53
Table 10: Benefits of Integrating Entanglement Theories and Speculative Design	54
Table 11: Comparison of Common Elements Across Entanglement Theories.	58
Table 12: Comparison across research paradigms.	85
Table 13: Evaluation Criteria Based on Post-Anthropocentric Principles.	101
Table 14: Design Reflections Based on the Types of Technological Mediation.	107
Table 15: Proposed solutions for the identified implications.	108
Table 16: Responsibilities assigned to different actants, categorized by implication codes (Group 1).	110
Table 17: Reflections on Design Aspects Based on Mediation Types.	112
Table 18: Responsibilities assigned to different actants, categorized by implication codes (Group 2).	114
Table 19: Proposed solutions for the implications, categorized by implication codes (Group 3).	116

Table 20: Responsibilities assigned to different actants, categorized by implication codes (Group 3).	118
Table 21: Proposed solutions for the identified implications (Group 4).	121
Table 22: Responsibilities assigned to different actants, categorized by implication codes (Group 4).	122
Table 23: Summary of the initial results.	124
Table 24: Quantitative distribution of future implications mapped by area.	125
Table 25: Types of mediation addressed by group and total occurrences.	125
Table 26: Quantitative distribution of responsibilities.	126
Table 27: Interpretive synthesis of the qualitative results of the workshop.	132
Table 28: Detailed Research Sub-Questions	172
Table 29: Inclusion Criteria for Document Selection	173
Table 30: Exclusion Criteria for Document Selection	173
Table 31: Criteria for Selecting Databases for Bibliometric Analysis	174
Table 32: General Overview of the Bibliometric Data	177
Table 33: Country-Level Production and International Collaboration	178
Table 34: Most Cited Works from External Sources (Ordered by TCpY)	181
Table 35: Most Cited External References in the Analyzed Documents	184

List of Nomenclatures

AIME	An Inquiry into Modes of Existence
AI	Artificial Intelligence
ANT	Actor–Network Theory
API	Application Programming Interface
ARCS	Attention, Relevance, Confidence, Satisfaction
AR	Agential Realism
BETs	Betting Platforms
CAAE	Certificate of Presentation for Ethical Consideration
CAM	Conceptual Analysis Method
CEP	Research Ethics Committee
GenAI	Generative Artificial Intelligence
HCD	Human-Centered Design
HCI	Human–Computer Interaction
HAI	Human–Agent Interaction
HRI	Human–Robot Interaction
IoT	Internet of Things
IHC	Human–Computer Interaction (Brazilian Symposium)
IS	Information Systems
ISI	Institute for Scientific Information
IT	Information Technology
LGPD	Brazilian General Data Protection Law
MHP	Mental Health Professionals
MtHD	More-than-Human Design
OOO	Object-Oriented Ontology
PD	Participatory Design
PDIA	Problem-Driven Iterative Adaptation
PF	Postphenomenology
PSD	Participatory Speculative Design
RtD	Research-through-Design
SAwD	Socially Aware Design
SBSI	Brazilian Symposium on Information Systems
SDGs	Sustainable Development Goals
SEF	Sociotechnical Entanglement Framework
SLM	Systematic Literature Mapping
SR	Speculative Realism
STS	Science and Technology Studies
TCLE	Informed Consent Form
TTM	Theory of Technological Mediation
VR	Virtual Reality
VRP	Virtual Reality Platform

1. Introduction

This chapter confronts the reader with the need to rethink how technologies and sociotechnical realities are constituted, especially when traditional approaches remain dependent on the modern bifurcation between nature and culture and on an ideal of technical neutrality that no longer accounts for the complexity of the present. By problematizing this context, the chapter establishes the basis for proposing a post-anthropocentric approach capable of understanding and intervening in sociotechnical ecosystems in a more relational way and with greater sensitivity to the materialities that compose them.

In addition, the chapter presents the motivations that emerge from professional practice, educational experiences, and philosophical concerns that guided this investigation. These motivations unfold into the formulation of the research problem and into the definition of the general and specific objectives. This foundation is further strengthened by the alignment of the dissertation with contemporary research agendas in Information Systems (IS), Human-Computer Interaction (HCI), and Computing Education, as well as with the Sustainable Development Goals. Building on these alignments, the chapter concludes by detailing the scientific, technical, social, and educational relevance of the study, demonstrating how the pursuit of more responsible sociotechnical futures depends on critical and speculative methodologies.

Finally, the chapter presents the methodological organization of the dissertation, outlining the internal logic that articulates theory, conceptual proposal, tools, empirical workshops, and analyses. This structure guides the reader through the subsequent steps, in which the theoretical foundations and constitutive elements of the Entanglement Theories begin to take shape.

1.1 Contextualization

Living in a world mediated by IS increasingly means inhabiting networks of relations that intertwine the technical and the social, the human and the non-human. However, IS have been designed largely on the basis of technicist and reductionist models (Lin, 2021; Balanay; Halog, 2021), which tend to simplify the relationships among social, natural, and technological phenomena (Gershenson, 2013). This tendency is evident both in scientific research in IS and in the Computing field more broadly, which remains strongly oriented by a positivist view centered on technical efficiency and market-driven demands (Malik; Malik, 2021). In the educational domain, this logic is reflected in the predominance of technical training over sociotechnical formation, which limits critical thinking on the ethical and social implications of technology (Morales-Navarro; Kafai, 2023).

In professional practice, technicism manifests itself clearly, for example, in the software development process. The very notion of stakeholders tends to be restricted to sponsors, direct users, and occasionally a few indirect users, disregarding

underrepresented communities, institutions with indirect influence, secondary stakeholders, and even the environment, which is systematically excluded from design decisions (Hyrynsalmi *et al.*, 2025). Furthermore, the values and interests embedded in algorithms and APIs (Application Programming Interface) remain invisible, even though they play a mediating and normative role in the sociotechnical practices that shape the digital ecosystem (Meluso *et al.*, 2025; Akter *et al.*, 2023).

The requirements gathering stage also reveals this reductionist bias. The traditional distinction between functional and non-functional requirements expresses a fragmented view of reality, since it treats interdependent aspects in isolation (Eckhardt *et al.*, 2016). This artificial categorization prevents the recognition of the multiple entangled dimensions that constitute a sociotechnical system. As a consequence, everything that can be codified tends to receive priority (Duboc *et al.*, 2019). Requirements therefore become confined to a narrow technical context, dissociated from their ethical, social, and long-term implications, such as care for users and the lasting effects of the solutions being designed.

During prototyping and testing, the emphasis typically falls on metrics such as response time, data throughput, and system accuracy (Schaffernak *et al.*, 2025). Although these aspects are relevant, they do not exhaust the concept of quality. Quality should also encompass values such as diversity, ethical responsibility, and future sustainability (McGuire *et al.*, 2023). Even design thinking practices, such as persona creation, often fall into stereotypes, simplifying the complexity of human experiences and reinforcing structural biases (Güneş; Görgün, 2022; Wang *et al.*, 2025).

Finally, in the deployment phase, haste and the logic of generalized automation tend to prevail. Practices such as DevOps are often conducted in an almost industrial manner, prioritizing operational efficiency over deeper reflection on the meanings and consequences of automation (Hansen, 2023). It is rarely questioned whether automated processes are aligned with organizational values, the sociocultural contexts involved, or the environmental impact associated with energy consumption (Leitoniene; Kundeliene, 2021). This relentless pursuit of innovation therefore tends to obscure the ethical and political character of designing systems.

Although effective for addressing structured and predictable problems, these systems show limitations when confronted with contemporary complexity, which is characterized by dynamic interdependencies, uncertainties, and large-scale sociotechnical impacts (Judge; Elahi, 2022). This limitation is not merely the result of technological constraints but stems from a historical-philosophical legacy (Balz, 1934) that has shaped the very way reality is understood and, consequently, how technologies are structured.

At this point, it becomes necessary to revisit the epistemological roots that sustain modern technical thought, particularly the paradigm of separation between nature and culture, whose legacy still reverberates in contemporary Computing.

1.1.1 The Paradigm of the Nature-Culture Bifurcation

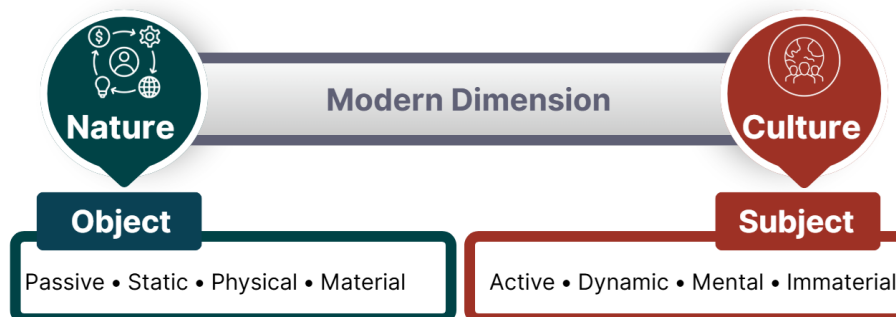
Among the most influential milestones of this legacy is the paradigm of the bifurcation of nature (Balz, 1934), consolidated in the seventeenth century. The process of bifurcation

emerged from the confrontation between two opposing philosophical currents that sought to explain reality: Leibniz's monism and Descartes's dualism (Latour, 2012; Velmans, 2007). Leibniz defended the existence of a single fundamental and indivisible substance that composes all things (Cassells, 2019). Descartes, in turn, argued for the existence of two independent worlds: the physical world, composed of extended things (*res extensa*) governed by natural laws, and the metaphysical world, composed of non-extended entities (*res cogitans*) such as mind and soul, governed by their own laws (Taliaferro, 1964).

While monism proposed a holistic and interdependent view of reality, dualism introduced a rigid separation between the physical and the mental worlds. The Cartesian perspective prevailed, shifting the notion of truth from the divine existence that dominated medieval thought to the *cogito*¹. Modern science incorporated this dualism by treating consciousness as a brain state or function and establishing a lasting metaphysical relationship between subject and object. In this arrangement, the subject is active and dominant, while the object is passive and reduced to measurable and manipulable attributes. The bifurcation between subject and object quickly extended to the separation between the social and the natural, influencing modern ways of knowing, acting, and designing technologies.

Figure 1 illustrates the modern view that segments reality into two poles: nature, understood as a physical, static, and material domain, and culture (or society), which encompasses human values, beliefs, and institutions. This conception has shaped Western habits and institutions (Latour, 1993, pp. 206-209).

Figure 1: Modern separation between the poles of nature and culture.



Source: Adapted from Latour (2012, p. 39)

Thus, many Western customs and habits were historically constructed around specific interests driven by the separation between the natural and the social worlds (Latour, 1993, pp. 206-209), influencing the very way we conceive technological systems and their boundaries.

1.1.2 Critique of Modern Scientific Thought

The current limitations of IS in the face of sociotechnical complexity can be understood in light of how modern scientific thought consolidated the paradigm of bifurcation. By separating nature and culture, this model structured scientific and

¹ *Cogito* comes from the Latin *cogitare*, "to think."

technological practices on rigid foundations, isolating the environment from its observer and conceiving knowledge as a purified activity restricted to specific domains (Latour, 2005b; Latour, 1993). Since the Enlightenment, disciplines such as mathematics, physics, and later engineering have become pillars of a scientific ideal grounded in objectivity, predictability, and control (Feenberg, 2008).

In the first half of the twentieth century, Whitehead (1925) had already criticized this dichotomy by arguing that reality is composed of interconnected processes. For him, the paradigm of bifurcation creates an epistemic fallacy by dividing the world into “primary qualities,” which are measurable facts independent of perception, and “secondary qualities,” which are subjective sensory perceptions. Technology exemplifies this neglected interdependence: systems such as social media platforms operate through the interaction between physical infrastructure (data, algorithms, energy) and human experiences, dimensions that the bifurcated view treats separately.

Latour (2012) reinforces that this fragmentation excludes hybrid elements such as technology, art, and politics, which do not fit neatly into either the natural or the social poles. Positivism, by prioritizing only objective facts, and materialism, by treating matter as the sole source of reality, consolidated the hierarchy between the natural and the social, strengthening an anthropocentric bias. In the IS field, this bias manifests itself in the predominance of models oriented toward “clean” data isolated from their contexts of production, ignoring the fact that any technological system results from multiple mediations between human and non-human actors (Alexander; Silvis, 2014). By reproducing the bifurcated logic, the field tends to treat complex problems as decontextualized technical issues, which makes it difficult to understand their ethical, political, and environmental implications.

Over time, technofetishist logic became more pronounced. The development of software engineering, especially after the so-called “software crisis” of the 1960s (Randell, 1996), intensified the search for formal methods such as mathematical modeling and correctness proofs (Dijkstra, 1976), consolidating the view of Computing as an exact science oriented toward efficiency and predictability. Even initiatives that proposed partial ruptures, such as the Agile Manifesto (Beck *et al.*, 2001), maintained their focus on productivity and adaptability without questioning the epistemological and political foundations of the field. As a result, a technical-instrumental model persists, one that views technology as a neutral means to predefined ends, obscuring its ethical, political, and environmental dimensions.

In the contemporary context, this reductionist orientation continues through the phenomenon of the “datafication of life” (Blok, 2023), which assumes that aspects of human experience can be converted into analyzable data. The advancement of big data, machine learning, and predictive algorithms has strengthened the belief that complex decisions in areas such as healthcare (Sarker, 2024), security (Andrade *et al.*, 2024), education (Xi, 2024), and financial markets (Prabakar *et al.*, 2024) can be automated based on statistical patterns, marginalizing the sociocultural contexts from which these data emerge. This logic of total quantification, sustained by a late positivism (Park *et al.*, 2020), disregards what cannot be measured and reinforces a view of Computing that overlooks its social, political, cultural, and environmental consequences.

This critique of the epistemological foundations of contemporary IS creates space

for rethinking the role of design and its responsibility in shaping futures, leading to the discussion that follows.

1.2 Motivation

In recent decades, the role of design has expanded beyond the creation of aesthetically pleasing or functionally efficient artifacts. It has come to be recognized as an active agent in the configuration of social, cultural, and technological realities, influencing not only the present but also shaping pathways toward the future. In a global context marked by rapid technological transformations, environmental challenges, and sociopolitical tensions, understanding how different design approaches shape these trajectories becomes essential for anticipating consequences, guiding practices, and proposing responsible interventions. Within this horizon, it is important to highlight that the choice of design approaches entails specific ontological and ethical commitments, with performative effects on sociotechnical networks. It is within this context that the reflection on distinct forms of design and their impact on the construction of possible futures is situated.

Conventional design, which is centered on the present, is dedicated to developing products, services, and systems that address immediate needs and encompass aesthetic, functional, and commercial aspects (Johannessen *et al.*, 2019). This approach, oriented toward pragmatic and direct solutions, has an undeniable impact on the future. In addition to responding to concrete demands, it often operates through the creation of desires and the stimulation of sensations and experiences aimed at capturing users' attention (Torre *et al.*, 2025). This movement, associated with market logics, fuels hyperconsumerism and contributes to the deepening of distortions in societal values, in which “having” tends to prevail over “being.” The choices made in the design and implementation of solutions therefore go beyond the mere satisfaction of current requirements; they establish sociotechnical trajectories that shape society and influence the course of innovation (Johannessen *et al.*, 2019).

From this perspective, design transcends the mere materialization of ideas and manifests itself as an intentional act that, even when not explicitly planned, aligns with a future-oriented vision. Its power to set trends is expressed through prototypes, models, and plans that seek to give form to realities that have not yet materialized (Johannessen *et al.*, 2019). As Susan Yelavich succinctly states, “design always creates the future” (Yelavich; Adams, 2014).

This vocation for the future becomes more pronounced in what is commonly referred to as modern design, which displays a natural affinity with the future marked by a conscious decision to break with the past. The desire for innovation characteristic of modernity promotes an evolution that departs from the gradual development typical of conventional design, accelerating the pace of creation and driving the emergence of new categories of objects with no historical precedent (Blauvelt, 2020). However, this acceleration raises a critical question: what kind of future are we unfolding through the incessant creation of new objects? Such a question invites a broader analysis in which technological development within the design context appears permeated by a growing

objectification. In this scenario, capitalist accelerationism, fueled by technological innovation (particularly in computing) has intensified transformations in social, economic, and environmental spheres (Levy, 2021).

By situating itself within this landscape, modern design not only projects potential futures through innovations and visual representations but also integrates an ecosystem sustained by hyperconsumption and hypercapitalism. This dynamic is evident in the practices of GAFAM companies (Google, Apple, Facebook, Amazon, and Microsoft), whose “invisible” digital infrastructures influence consumption behaviors and redefine concepts of governance and control (Parra *et al.*, 2018). When technological advancement is guided primarily by efficiency and technical performance, issues such as social justice, ethics, and sustainability tend to be systematically overlooked (Malik; Malik, 2021; Selbst *et al.*, 2019).

This omission does not arise solely from design choices or corporate strategies; it is rooted in the very formation of the Computing field. Historically, academic curricula have privileged technical subjects such as Programming, Systems Modeling, and Networks, relegating to the background the sociotechnical dimensions that are fundamental for understanding the interdependence between technology and society (Malik; Malik, 2021; Zorzo *et al.*, 2017). This reproduces in Computing education the bifurcated model that separates the technical from the social. Only a few areas, such as HCI and IS, explore topics such as usability and Computer Ethics, and even then in a limited manner. These approaches tend to focus on isolated aspects without deepening the sociotechnical contexts and dynamics that shape the relations between humans and artifacts (Selbst *et al.*, 2019; Connolly, 2020).

It was from this set of perspectives that Frauenberger (2019) proposed a new paradigm called “Entanglement HCI.” Frauenberger (2019) groups these approaches under the label Entanglement Theories² precisely because they share a common commitment to a relational and performative ontology. In contrast to positivist and representationalist traditions, Entanglement HCI understands humans and technologies as co-emergent entities. Thus, design is no longer viewed as a mere mediation between subject and object; it is understood instead as a practice that produces realities, with inseparable ontological, epistemological, and ethical implications.

This new framing resonates directly with the principles of Speculative Design³ (Mitrović *et al.*, 2021), which also rejects instrumental purposes and proposes the creation of provocative artifacts and scenarios as a way of questioning possible futures. Both approaches recognize that designing technology is simultaneously designing worlds, and therefore require ethical responsibility in how they shape the materializations of the future. In this sense, the Entanglement Theories could offer robust theoretical foundations to support speculative practices committed to complexity, uncertainty, and sociotechnical transformation.

²The Entanglement Theories will be detailed in Sections 2.2 to 2.5.

³Speculative Design will be detailed in Section 2.6.

1.3 Research Problem

The crises of the Anthropocene (Mellamphy; Vangeest, 2024) impose increasingly complex challenges on society. The depletion of natural resources, the intensification of extreme climatic events, the weakening of democratic institutions, and the growing subordination of nation-states to technological conglomerates are some of the phenomena that characterize this scenario. More recently, debates emerging from posthumanism and transhumanism have expanded these concerns by raising questions about the increasing fusion between humans and technologies, with the potential to deepen social inequalities and exacerbate asymmetries of access and autonomy (Öngören, 2024).

Although these phenomena may appear isolated, they are deeply interconnected in a complex web of relations between humans and non-humans, giving rise to new forms of interaction, social values, and power relations (Latour, 2005a; Barad, 2007). These interactions are not limited to unidirectional impacts; rather, they configure processes of co-constitution of sociotechnical realities in which humans and technologies mutually shape one another. Each technical innovation therefore not only responds to social demands but also reconfigures practices, institutions, and ways of inhabiting the world, revealing that sociotechnical reality emerges as an entangled fabric in constant transformation. For this reason, it has been analyzed from multiple perspectives, including ecology (Perrin; Dorrell, 2024), politics (Anthias; Asher, 2024), the social sciences (Latour, 2018), philosophy (Mellamphy; Vangeest, 2024), and technology (Siqueira, 2025; Verbeek, 2005b), making it clear that no single discipline can offer complete answers to these challenges.

The Anthropocene is an era shaped by Western values, intrinsically tied to the modernist worldview and driven by the Industrial Revolution. This period consolidated a vision of progress based on the supremacy of reason and on the optimistic belief that technological acceleration could solve human problems (Wijarnarko; Maharani, 2024). Technological acceleration was not only a requirement of capitalism but also contributed to shaping it, becoming one of its main vectors of expansion. As a result, major companies in the sector accumulated unprecedented economic and political power, directing innovation toward the interests of capital and the maximization of profit.

The persistence of this accelerationist techno-perspective, combined with the predominance of technocentrism focused exclusively on human needs, exposes the fragility of the belief in linear progress sustained by Enlightenment narratives over the past two centuries (Latour, 2012). The Cartesian logic that underpins this worldview has overshadowed alternative forms of knowledge and non-Western epistemologies, limiting the ability of technology to respond effectively to the crises of the Anthropocene (Latour, 2018; Santos, 2000). By disregarding other worldviews and relational ontologies, our understanding of the complex interactions among humans, non-humans, and digital infrastructures in shaping emerging phenomena becomes compromised (Barad, 2007).

In this context, technicism functions as a strategy for the depoliticization of technology, naturalizing asymmetries and reinforcing the illusion of neutrality in sociotechnical systems (Winner, 2017). Large corporations such as Google and Facebook, whose business models depend on massive data extraction, intensify power imbalances by mediating human interactions in asymmetric ways. These platforms

shape user behavior by privileging certain groups while subjecting others to surveillance and control (Zuboff, 2023). Central technologies of the contemporary era, such as AI and search engines, act as agents of epistemic mediation, filtering, ranking, and often distorting the information accessed, thereby reinforcing inequalities and influencing social perceptions (Noble, 2018; Zuboff, 2023).

Despite the central role that technology plays in shaping these new sociotechnical ecologies, the responses offered by research, Information Systems education, and professional practice remain limited. This limitation reveals a gap between the recognition of the global problems of the Anthropocene and the ways in which the field conceives, teaches, and implements technological solutions.

Thus, the **problem** that guides this dissertation lies in the way technological design has been conducted: it is often treated as a purely technical activity, without sufficient critical thinking on the ethical, social, and environmental implications involved in the act of designing. This limitation reduces the reflective potential of design and results in a fragmented understanding of the multiple dimensions that constitute sociotechnical reality. Although topics such as sustainable computing, algorithmic ethics, and technological responsibility have been discussed, current proposals still struggle to translate sociomaterial and post-anthropocentric insights into operational design practices. Their theoretical density and conceptual complexity frequently hinder their adoption in Information Systems design, limiting their practical applicability in navigating contemporary sociotechnical complexity.

1.4 Research Objectives

To address the research problem presented above, it becomes necessary to rethink the role of Computing and, in particular, the design of information systems in shaping contemporary sociotechnical realities. More than proposing technical solutions, the task is to understand the act of designing as a mediating and performative practice in which technology actively participates in the ways of existing, knowing, and acting in the world. This shift in perspective requires approaches capable of integrating theory and practice, technique and ethics, thinking and action, fostering forms of design that are sensitive to the interdependencies among humans, non-humans, and digital infrastructures.

In this context, this dissertation adopts as its theoretical lenses the integration between Speculative Design and the Entanglement Theories, which include Actor-Network Theory (ANT) (Latour, 2005a), Speculative Realism (Harman, 2018), Agential Realism (Barad, 2007), and Postphenomenology with the Theory of Technological Mediation (Verbeek, 2005b). By incorporating these frameworks, the aim is to broaden the understanding of technological design as a situated and relational practice, encouraging a critical and creative stance toward the ethical, political, and material implications of what is designed.

Thus, the **general objective** of this dissertation is to investigate how Speculative Design, grounded in the Entanglement Theories, can offer ways to reorient the act of designing technologies toward a more ethical, responsible, and post-anthropocentric practice.

To achieve this objective, a set of specific objectives was developed:

1. Analyze how Entanglement Theories have been explored in research and practices related to IS and Speculative Design.
2. Develop a framework that translates the principles of Entanglement Theories into applicable Speculative Design practices.
3. Create and systematize support tools for the Speculative Design framework incorporating Entanglement Theories.
4. Apply the framework and its tools in Speculative Design workshops, involving participants in future speculation and reflection on sociotechnical responsibilities.
5. Evaluate, based on workshop results, the potential of the framework for designing post-anthropocentric technologies, articulating Entanglement Theories and Speculative Design.

1.5 Alignment of the Research with the Major Themes in IS, HCI, and Computing Education

Within the **field of IS**, the work aligns closely with the challenge “Sociotechnical Perspectives, Macro-Trends, and Plural Worldviews” presented in GrandSI-BR 2026–2036 (Sociedade Brasileira de Computação, 2025b). This agenda urges the field to move beyond technicist perspectives and to embrace diverse ontologies, temporalities, and forms of agency in order to understand how humans, technologies, and organizations are co-constituted.

This perspective is consistent with international developments. As Brocke *et al.* (2015) observes, global transformations toward sustainability require IS research to engage with deeply entangled infrastructures, distributed agency, and long-term socioecological transitions. Similarly, Karwowski *et al.* (2025) emphasizes that contemporary issues such as climate change and AI governance are systemic, interdependent, and inherently sociotechnical, demanding interdisciplinary approaches that integrate modeling, design, and scenario-based methods. In addition, Wolff *et al.* (2022) highlights that although part of IS research addresses global priorities like health, sustainable cities, and innovation, a substantial segment of the field remains oriented toward internal or market-driven agendas, limiting its contribution to broader societal transformations. Together, these authors call for conceptual and methodological shifts that would enable IS to engage more effectively with planetary sustainability, social justice, and systemic resilience.

This dissertation responds to that call by advancing a post-anthropocentric framework capable of mapping, analyzing, and intervening in complex sociotechnical ecosystems. By integrating grounded speculation with critical analysis of macro-trends, it offers conceptual and methodological tools to engage with the intricate dynamics shaping contemporary sociotechnical realities.

In the **field of HCI**, this dissertation resonates with the challenge “New Theoretical and Methodological Approaches in HCI” from GranDIHC-BR 2025-2035 (Junior *et al.*, 2024), which highlights the need for new epistemological and methodological foundations to understand hybrid phenomena mediated by ubiquitous, intelligent, and socially disruptive technologies. The articulation among ANT, Agential Realism, Speculative Realism, and Postphenomenology, combined with the practice of speculative design, broadens the conceptual and methodological repertoire available for investigating and designing distributed, ethical, and context-sensitive interactions.

The 2025 update of the “Seven HCI Grand Challenges” underscores that emerging AI ecosystems demand forms of interaction that are explainable, value-aligned, privacy-preserving, and culturally sensitive, while simultaneously exposing persistent challenges related to over-reliance, opacity, and asymmetries of control (Stephanidis *et al.*, 2025). Such findings further underscore the relevance of post-anthropocentric perspectives capable of examining how technologies co-configure bodies, practices, environments, and institutions.

In this sense, the dissertation directly addresses the themes identified as priorities: sociotechnical ethics and justice, distributed agency, futures of interaction, and innovative methods. It provides robust analytical and methodological pathways for understanding how emerging technologies reconfigure identities, practices, and institutions.

In **Computing Education**, this dissertation aligns with the “Grand Challenges of Computing Education in Brazil” (GEducomp 2025–2035) (Sociedade Brasileira de Computação, 2025a), particularly with the two themes: (i) “Skills and Competencies in Computing Learning,” which emphasizes the urgency of preparing students who are capable of thinking critically about technology, developing socioemotional competencies, and understanding the ethical and sociotechnical dimensions of Computing; (ii) “Artificial Intelligence as an Agent in Computing Education,” by examining the impacts of AI on authorship, learning, and autonomy, and by proposing educational approaches that treat Computing as a situated, relational, and cultural field. It is also aligned with the “Grand Challenges in Engineering and Computing Education” (Bego *et al.*, 2024), which highlight the need to fully prepare and empower students to address complex, open-ended, and/or ill-defined societal problems.

The tools and methods proposed in this dissertation provide direct support for critical, creative, and reflective education by fostering sociotechnical literacy and the ability to design futures with responsibility.

1.6 Alignment of the Research with the Sustainable Development Goals

The 2030 Agenda understands the Sustainable Development Goals (SDGs) as a global commitment to promote prosperity, social justice, and sustainability, and it recognizes science, technology, and innovation as fundamental pillars of this effort (Assembly, 2015). By emphasizing dignity, inclusion, and critical capacities, the document points to the need for educational approaches that strengthen critical thinking and sociotechnical responsibility, principles that are incorporated into the workshops and tools developed in this dissertation.

The document “Pact for the Future, Global Digital Compact and Declaration on Future Generations” reinforces this orientation by calling for ethical action, international cooperation, and responsible governance of emerging technologies. The text warns of digital risks and inequalities intensified by AI and advocates for transparent and intergenerational decision-making processes (United Nations, 2024). In a complementary way, the report “Frontier Technologies for Sustainable Development” emphasizes that AI, automation, and biotechnologies promote sustainable development only when accompanied by critical reflection, mitigation of inequalities, and the strengthening of human capabilities (Sanders *et al.*, 2018). This perspective converges with the focus of the dissertation on analyzing technological mediations, power asymmetries, and distributed impacts within the sociotechnical ecosystems that are mapped and designed.

Based on each document and its corresponding guidelines, this dissertation aligns with different SDGs in distinct and complementary ways:

- **SDG 4: Quality Education** emphasizes the development of capabilities, critical thinking, and lifelong learning (Assembly, 2015). This dissertation contributes directly to this goal by proposing speculative design workshops and pedagogical tools that strengthen reflective and ethical competencies and prepare participants to understand and design technologies in a responsible manner.
- **SDG 9: Industry, Innovation, and Infrastructure** highlights that sustainable innovation requires critical governance of technologies (Sanders *et al.*, 2018). This dissertation responds to this challenge by offering methods and instruments that guide innovation processes beyond technicism and incorporate distributed agency, implicated materialities, and sociotechnical impacts.
- **SDG 10: Reduced Inequalities** stresses that digital, economic, and political inequalities are amplified when emerging technologies are not accompanied by principles of social justice and ethical governance (United Nations, 2024). By mapping asymmetries within sociotechnical ecosystems and proposing futures that mitigate them, the dissertation contributes to reducing these inequalities.
- **SDG 16: Peace, Justice, and Strong Institutions** underscores the need for transparent, participatory, and accountable institutions to address contemporary sociotechnical challenges (Assembly, 2015; United Nations, 2024). The framework developed in this dissertation supports qualified deliberation, controversy analysis, understanding of mediations, and collective decision-making, which directly advance this goal.
- **SDG 17: Partnerships for the Goals** highlights that global sociotechnical challenges require multisector and interinstitutional cooperation (United Nations, 2024). This research incorporates this principle by integrating researchers, students, technologies, and institutions in collaborative speculative practices that promote shared and co-responsible visions of the future.

1.7 Research Relevance

The relevance of this research lies in expanding the sociotechnical understanding of technological design beyond the act of designing itself (Frauenberger, 2019). From this perspective, designing is no longer a practice restricted to developers of databases, systems, algorithms, digital infrastructures, or computational architectures (Smaldino *et al.*, 2025). Everyone who is part of a sociotechnical ecosystem, including users, regulators, professionals, and individuals affected by informational decisions, participates to varying degrees in shaping the ways in which information circulates, becomes organized, and acquires meaning in the world (Hespanhol, 2023).

In this sense, in a context in which we are all immersed in digital ecosystems, the relevance of this research transcends the work of professionals, educators, and researchers in IS and HCI. Even though it does not directly analyze other fields, this study can be appropriated by multiple domains, serving as an invitation to reflect on the interdependencies among technology, society, the environment, and knowledge production practices.

For example, in the legal field, this research could support critical reflections on power structures, inequalities in access to justice, and the sociotechnical effects of emerging legal technologies. The study by Dabaghi (2022) shows how speculative design can be employed to explore the normative and political consequences of adopting digital governance systems, creating scenarios that make visible possible alternative arrangements of justice, accountability, and public participation. In a complementary way, this research could also contribute to anticipating technological trends in the legal domain and their social and regulatory implications, as demonstrated by Rossi *et al.* (2022), who examines the interaction between laws, norms, and emerging technologies and employs exercises of regulatory imagination that involve regulators, experts, and citizens in constructing plausible regulatory futures.

In the economic field, this research can provide important support for stimulating reflections on alternative and more equitable economic models (Dillahunt *et al.*, 2023). The speculative design literature has shown that this approach helps problematize the growing influence of digital banks, fintech companies, and automated services, making it possible to envision potential reconfigurations of agency, power, and access within these ecosystems (Elsden *et al.*, 2020; Elsden *et al.*, 2022; Elsden *et al.*, 2024). Similarly, studies that speculate about alternative currencies and cryptocurrencies demonstrate how different monetary arrangements activate diverse social imaginaries and can generate long-term impacts on economic practices and institutional relations (Mandirola, 2025; Lindley, 2015; Keere; Milan, 2025). In this sense, this research can support integrated discussions about the future effects of financial innovations and about the kinds of desirable futures to be designed, articulating concerns related to innovation, sustainability, and equity (Mandirola, 2025).

In personal relationships, the speculative and relational thinking proposed here could support critical reflections on the ways digital platforms shape interactions, social bonds, and affective experiences. Recent studies show that speculative design is a productive path for problematizing and reimagining these ecosystems. The work of Hohendanner *et al.* (2024), for example, demonstrates how participatory speculative exercises allow

the exploration of future forms of socialization in immersive environments, bringing to light concerns related to identity, belonging, inequality, and new forms of exclusion and agency in the metaverse. This research could also support collective experiences that help participants understand how speculative futures may foster institutional transformations. Approaches such as the one presented in the study by [Aranda-Munoz et al. \(2025\)](#) show that experiencing possible futures, rather than engaging in purely abstract discussions, can generate critical awareness of the practices and structures that sustain social platforms, recommendation algorithms, and regimes of online visibility.

Finally, in the sphere of personal growth, the post-anthropocentric principles that ground this dissertation can inspire new ways of thinking and acting in the world, inviting individuals to recognize their position within broader networks of coexistence and interdependence. Decentering the human within ontology expands our capacity to understand value, agency, and responsibility beyond the human species, redefining the ways we relate to the environment, to technologies, and to other forms of life ([Ferrando, 2016](#); [Susen, 2022](#)). This shift in perspective strengthens practices of care, reciprocity, and shared responsibility, contributing to an ethics that is more attentive to the multiple forms of being and existing that compose the world. Similarly, studies that articulate posthumanism and sustainability show that overcoming anthropocentric paradigms is fundamental for rethinking systems of consumption and ecological relations, encouraging practices that acknowledge the interdependence among humans, nature, and technical artifacts ([Dedeoğlu; Zampaki, 2023](#)). This expanded sensibility also directly affects processes of self-understanding and personal development, leading individuals to perceive that their actions are not confined to the “self,” but instead continuously participate in the maintenance and transformation of social, environmental, and technological ecosystems.

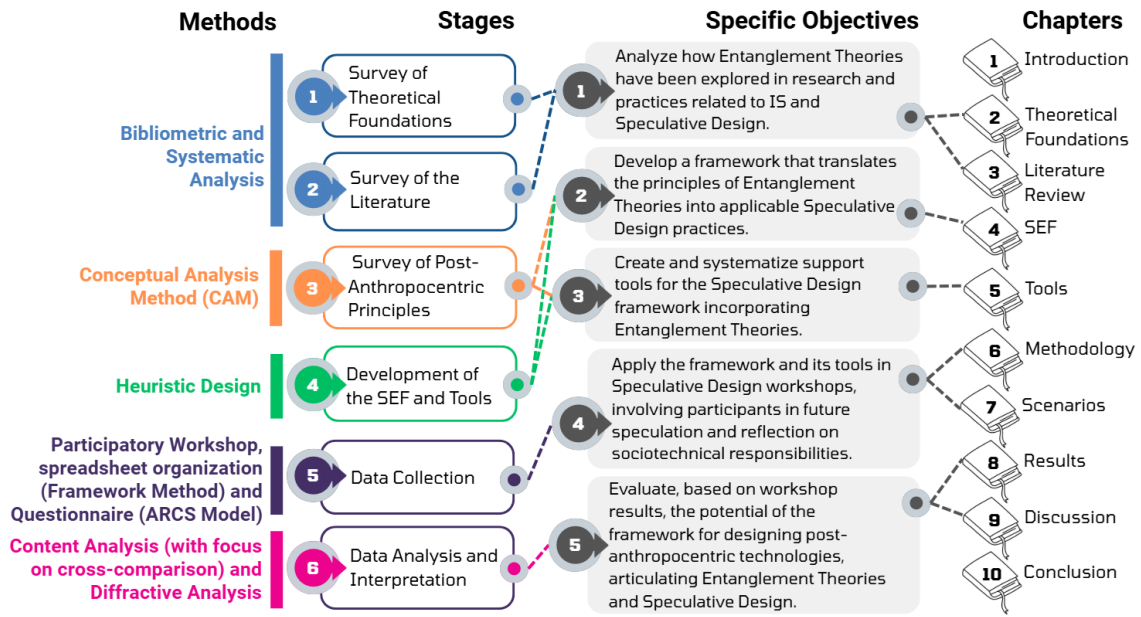
1.8 Methodological Organization of the Dissertation

In addition to this introductory chapter, the dissertation is organized in a way that aligns its chapters with the specific objectives of the research. The methodological structure was designed to make clear the relationship among the methods employed, the stages of the research, and the specific objectives associated with each stage. This organization is presented in Figure [2](#).

The first two stages, which involve the Survey of Theoretical Foundations and the Literature Review, were grounded in bibliometric and systematic analyses aimed at identifying and examining how Entanglement Theories have been explored in research and practices related to IS and Speculative Design. These stages correspond to Chapters [2](#) and [3](#), which present the theoretical foundations and the mapping of the most relevant publications, trends, and gaps that support the development of the study.

The third stage, which concerns the Identification of Post-Anthropocentric Principles, was conducted using the Conceptual Analysis Method (CAM) ([Tähtinen; Havila, 2019](#)). This method was employed to extract and systematize principles that guide a post-anthropocentric approach to design. The process resulted in principles that translate the foundations of Entanglement Theories into practices applicable to

Figure 2: Dissertation Structure



Source: Author's own elaboration.

Speculative Design, addressing the second and third specific objectives of the research and supporting the conception of the framework and the tools presented in Chapters 4 and 5.

In the fourth stage, the SEF and its set of supporting tools were developed through a Heuristic Design process (Nielsen, 2005). This process made it possible to iteratively refine the artifacts, aligning them with the post-anthropocentric principles and with the Entanglement Theories. This stage also addresses the second and third specific objectives and is associated with Chapters 4 and 5, which present the framework and its tools.

The fifth stage corresponded to the Data Collection process, which was carried out through Participatory Speculative Design Workshops (Farias *et al.*, 2022; Ye; Zhang, 2024). In these workshops, participants were invited to apply the framework and its tools to speculate about possible futures and to reflect on sociotechnical responsibilities. The data collection involved transcribing and tabulating the material according to the Framework Method (Gale *et al.*, 2013; Klingberg *et al.*, 2024), as well as administering a questionnaire to participants after the workshop so they could record their perceptions. The data collection procedures and the methodological details of the workshop are presented in Chapter 6. The speculated scenarios and technological solutions produced by the participants are presented in Chapter 7.

The sixth stage corresponded to the analytical and interpretive phase of the research. In this phase, the data generated in the participatory workshop, including transcripts, spreadsheets, participant records, and questionnaire responses, were examined through Content Analysis with an emphasis on systematic comparison. This approach enabled the systematic comparison of categories, statements, and units of meaning, which made it possible to identify convergences, divergences, and tensions between the groups' perceptions and the post-anthropocentric principles that ground the SEF. In addition, the

diffractive method was also employed (Barad, 2007; Barad, 2014), understood as a mode of reading that privileges patterns of difference produced in the intra-actions among the data, the theories, and the analytical apparatuses. This perspective helped reveal how meanings emerged relationally within the phenomenon under investigation and expanded the interpretive depth of the analysis. The analytical results and their implications are discussed in Chapters 8 and 9.

Finally, Chapter 10 presents the overall conclusions of the research and discusses the theoretical, methodological, educational, and practical contributions achieved, as well as its limitations.

2. Entanglement Theories and Speculative Design

This chapter presents the theoretical foundations that support the proposal of this dissertation by introducing the Entanglement Theories and their articulation with Speculative Design. The theoretical discussion unfolds through the presentation of the four central strands of entanglement: ANT, Postphenomenology, Speculative Realism, and Agential Realism, each contributing specific perspectives. Throughout the chapter, these frameworks are described in an integrated manner, highlighting how their complementarities enable a more complex and relational understanding of design practices and contemporary technological ecosystems.

The chapter then discusses how Speculative Design is situated within this theoretical constellation and highlights future-oriented approaches, patterns of tension, and different types of toolkits identified in the literature.

2.1 Contextualization

Entanglement Theories seek to understand the phenomena that emerge from interactions between humans and non-humans (Frauenberger, 2019). At their core, these theories are often grouped under the labels of neo-materialist theories, new materialism, or relational approaches. Despite their differences, they share a fundamental principle: the separation between nature and culture, deeply rooted in Cartesian thought and still dominant today, is an artificial construction. This dichotomy has shaped the modern mindset, yet it must be dismantled if we are to understand reality in a non-dualistic way. The phenomena that surround us cannot be explained solely through technological determinism or social determinism¹ (Jordan, 2009). Instead, they emerge from the co-emergence of both.

This perspective challenges anthropocentrism by questioning the exclusive centrality of human experience in the constitution of reality. Its aim, however, is not to deny the importance of humans or technology, but to recognize that the materiality of the world is far more complex than a binary view allows. Reality emerges through intricate entanglements that require careful investigation (Barad, 2007, pp. 39-70), (Fox; Alldred, 2019; Wessells, 2007; Haraway, 2013a; Stengers, 2008). In this sense, these theories invite us to move beyond traditional divisions and to explore the multiple agencies that shape the world we inhabit.

Among these theories, this dissertation draws on four of them in the present study:

¹Technological determinism refers to the conception that technological change constitutes the primary, or even the sole, driving force of social transformation and implies that technical innovations unilaterally shape social, cultural, and political organization (Winner, 1978). Social determinism, in contrast, asserts that society, through its values, interests, and practices, determines the development, adoption, and uses of technologies (MacKenzie; Wajcman, 1999). Both perspectives, in their radical forms, have been criticized for neglecting the co-constitutive relationship between society and technology emphasized by science and technology studies (STS).

ANT, Speculative Realism, Agential Realism, and Postphenomenology. This selection was based on a study conducted by [Frauenberger \(2019\)](#), which identifies these theories as complementary and particularly relevant to the field of HCI. These theoretical approaches offer distinct yet interconnected perspectives that enrich the analysis of relations among humans, artifacts, and sociotechnical contexts. Table 1 presents a selection of seminal works that provide the theoretical foundations for each of these approaches².

Table 1: Seminal Works and Key Contributions for Each Theory.

Theory	Seminal Work	Year	Description
Actor-Network Theory (ANT)	<i>Science in Action: How to Follow Scientists and Engineers Through Society</i> (Latour, 1987)	1987	Explores how scientific and technological facts are constructed through heterogeneous networks of actors. Highlights the opening of “black boxes,” translation processes, controversies, and the interconnectedness between local and global contexts.
Postphenomenology (PF)	<i>Technology and the Lifeworld: From Garden to Earth</i> (Ihde, 1990)	1990	Investigates how technologies mediate and transform human relations with the world by defining specific types of technological mediation. Rejects both deterministic and instrumentalist perspectives.
Speculative Realism (SR)	<i>After Finitude: An Essay on the Necessity of Contingency</i> (Meillassoux, 2006)	2006	Critiques correlationism by questioning the idea that reality can only be accessed through perception or language and argues that reality can be accessed independently of subjective experience.
Agential Realism (AR)	<i>Meeting the Universe Halfway</i> (Barad, 2007)	2007	Introduces an innovative concept of performativity that goes beyond linguistic or social representations. Argues that reality is performatively constituted through relations, or intra-actions.

Source: Author’s elaboration.

These works form the conceptual foundation on which this dissertation is built. By providing analytical instruments to explain how technologies influence and transform human and non-human practices (mediations), to reveal entities that are rendered invisible, and to speculate about realities that are not reducible to human experience, these theories strengthen Speculative Design as a reflective approach that not only produces solutions but also questions the values, assumptions, and sociotechnical impacts associated with technologies. ANT enables the tracing of sociotechnical networks and their controversies; Postphenomenology illuminates the ways artifacts shape experience and action; Speculative Realism shifts the focus from empirical experience to the existence of withdrawn objects and non-given futures; and Agential Realism proposes a “diffractive” ethics, that is, a form of responsibility that emerges from the interaction between the material and the discursive and recognizes that world and knowledge are jointly produced.

In this dissertation, the integration of these approaches with Speculative Design is proposed, given their potential to foster practices of critical innovation. Speculative Design reorients the role of design by prioritizing the imagination of possible futures and reflection on the ethical, political, and sociotechnical implications of emerging technologies, rather than limiting itself to the functional resolution of immediate problems. By incorporating the Entanglement Theories, Speculative Design expands its

²This dissertation does not aim to provide a complete description of the theories, but rather an introduction to their main concepts, which is developed in the subsequent sections. Given the complexity of these frameworks, readers are encouraged to consult the specialized literature for a more comprehensive understanding.

capacity to engage with complex, unstable, and non-linear systems and acknowledges the distributed agency of humans and non-humans within sociotechnical ecosystems.

2.2 Actor-Network Theory

Actor-Network Theory (ANT), also known as the “Sociology of Associations,” emerged within the field of science and technology studies (STS), developed at the École des Mines de Paris³ by authors such as Michel Callon (1984) and Bruno Latour (1987). Over time, ANT began to incorporate a more explicit focus on technology (Latour, 1996a) and information (Latour, 1996b), outlining a trajectory that dialogues with the social construction of technology (Bijker *et al.*, 1987). This approach assumes that technologies are developed within specific sociotechnical contexts, which shape both the innovation processes and the resulting artifacts.

ANT is not a theory but a theoretical and methodological approach that is structured around five sources of uncertainty that challenge the fundamental assumptions of traditional sociology. These uncertainties are not obstacles to be eliminated but analytical cues that guide the empirical work of the researcher toward the associations that compose social reality.

2.2.1 Sources of Uncertainty in ANT

Table 2 presents a synthesis of these five sources of uncertainty and their main analytical implications.

Table 2: Sources of Uncertainty in ANT.

Source of Uncertainty	Description	Implications
No Group versus Group Formation:	Groups are not fixed entities but fluid and provisional assemblages.	The researcher must empirically trace how groupings are constituted and transformed within networks.
Isolated Action versus Distributed Action	Action is never isolated; it emerges from associations among multiple actors.	Explanations centered on isolated subjects must be abandoned.
Human and Non-human Agency	Objects are not passive; they are actants operating at the same explanatory level as humans.	Generalized Symmetry requires that actants receive equal analytical attention.
Matters of Fact and Matters of Concern	Facts are precarious effects of mediation, negotiation, and dispute.	Researchers must avoid treating facts as unquestionable or self-evident.
Risky Accounts	The researcher’s account intervenes in the very network it describes.	The account must be reflexive and preserve the agency of actors while avoiding narrative simplification.

Source: Author’s elaboration.

The first source of uncertainty (Latour, 2005a, pp. 27-42) states that there are no groups, only groupings. Instead of treating collectives as given and stable entities, ANT proposes that groupings are effects of continuous practices of categorization, inscription, and mobilization. They must be traced in their emergence and contestation rather than taken as analytical assumptions.

This idea has important implications. If there are no ready-made groups but only

³Official website of École des Mines de Paris: <https://www.minesparis.psl.eu/en/home/>

groupings in constant formation, the researcher cannot simply rely on fixed categories such as “society,” “organization,” or “users” as starting points. It becomes necessary to observe how these groupings are constructed in everyday practices, who names them, who speaks on their behalf, and which devices help to hold them together. Rather than applying predefined labels, the task becomes following the traces left by those who are attempting to form and stabilize the groupings.

The second source of uncertainty (Latour, 2005a, pp. 44-62) concerns the nature of action: action is always distributed. There is no isolated agent or clear point of origin, since every action is distributed and composed of humans and non-humans, devices, norms, codes, and artifacts that co-produce observable effects. Agency is relational and emergent.

This way of thinking about action profoundly transforms how we investigate social and technical phenomena. If action is always distributed, the researcher can no longer attribute it to a single agent such as a person, an institution, or a technology. Instead, it becomes necessary to trace the trajectory of the action and observe how it is produced by a network of heterogeneous elements that operate together. This requires close attention to detail: which tools were used, which norms were involved, which interpretations were mobilized, and which artifacts intervened. Agency ceases to be something that someone possesses and becomes something that occurs among many.

The third source of uncertainty (Latour, 2005a, pp. 63-86) highlights that objects can also exercise agency, not as an intrinsic attribute but as a relational effect. ANT challenges the modern separation between active subjects and passive objects by proposing that humans and non-humans should both be considered actants, that is, entities that make a difference within the networks in which they are embedded. In this view, agency emerges from concrete associations and mediations among heterogeneous elements. Objects are not merely background or support elements; they are active participants in the constitution of the social, capable of stabilizing, displacing, or transforming associations. For this reason, they must be taken seriously in sociological analysis.

This reconfiguration of agency requires the principle of “Generalized Symmetry,” according to which no ontological distinction should be presumed between humans and non-humans when analyzing sociotechnical phenomena. Rather than attributing social causes exclusively to humans and relegating objects to a role of context or consequence, symmetry proposes that both should be described with the same degree of explanatory attention. This does not mean that humans and objects are identical, but that both participate in the production of the social and must be empirically followed with equal care. In practice, this transforms how sociological analysis is conducted: it becomes necessary to include objects as active participants in the networks under investigation. A button, a spreadsheet, a traffic light, or an API are not merely supports for human action, they influence decisions, impose rhythms, organize behaviors, and even shape power relations.

The fourth source of uncertainty (Latour, 2005a, pp. 88-120) questions the very notion of fact by distinguishing between “matters of fact” and “matters of concern.” A fact is not a self-evident starting point but the unstable outcome of networks of mediation, dispute, and concern. It is necessary to follow how a fact takes shape, which voices support it,

which devices stabilize it, and which controversies traverse it. Something becomes a “matter of fact” only once it no longer generates concern, but until that point it remains a “matter of concern,” surrounded by uncertainties, negotiations, and disputes.

This perspective requires particular attention to the processes through which something becomes incontestable or, conversely, remains controversial. The analysis therefore shifts from asking what facts are to examining how they become what they are, tracing the networks that legitimize them, challenge them, or keep them alive in public debate.

The fifth and final source of uncertainty (Latour, 2005a, pp. 121-140) highlights the inherent risks of writing. Sociological narratives are never neutral; they intervene in the very networks they aim to describe. The researcher is therefore urged to craft accounts that preserve the agency and complexity of the actors, resisting the temptation to prematurely stabilize controversies. Writing, in this sense, becomes an active component of the associative processes under scrutiny, demanding reflexivity and responsibility.

This emphasis on writing underscores that reporting is itself a performative and interventionist practice. Through narrative choices, the researcher shapes which actors become visible, which controversies gain or lose momentum, and how the network is configured for the reader. In ANT, writing is thus inseparable from analysis, functioning not as a final stage of communication but as a constitutive moment in the very production of sociological knowledge.

By integrating these five sources of uncertainty, ANT proposes a profound reformulation of the task of sociology. Instead of treating the “social” as a substance or an autonomous domain of reality, ANT conceives it as the very movement of associations among heterogeneous elements (Latour, 2005a). This perspective reverses the traditional explanatory logic: the social does not explain phenomena; it is what must itself be explained. The researcher’s task, therefore, is to follow the humans and nonhumans that compose a network and observe how their interactions produce and transform sociotechnical reality.

From this perspective, the researcher’s task is to carefully follow the actants, their trajectories, and their traces in order to understand how the production and transformation of sociotechnical reality occurs in practice. This requires abandoning totalizing sociological explanations and adopting a descriptive and empirical posture. However, this investigative effort is far from trivial, especially when the researcher encounters what ANT refers to as black boxes.

2.2.2 Black Boxes

The concept of the black box (LEMOIS, 2007, p. 67) refers to elements that, once stabilized, operate in an apparently automatic manner, with their internal functioning left unquestioned. Such elements become opaque precisely because their underlying controversies have been provisionally settled, thereby naturalizing their roles and functions within the network. However, attaining a deeper understanding of a sociotechnical network requires the opposite movement: opening these black boxes, that is, tracing the negotiations, disputes, and alliances through which they were constituted.

This analytical gesture restores the complexity of sociotechnical arrangements, unsettling taken-for-granted assumptions and reintroducing contingency where stability once seemed assured. Analysis thus ceases to reproduce ready-made categories and instead describes, with precision and care, the dynamic fabric of networks in ongoing (re)configuration.

However, this type of analysis runs counter to a common tendency in the social sciences. In many cases, researchers are inclined to seek convenient explanations, relying on abstract categories, structural causes, or naturalized assumptions to account for complex phenomena.

2.2.3 Double Click

The concept of the double-click (Hind; Lammes, 2016) in ANT precisely illustrates this notion of apparent opacity to which many researchers are often led. When we double-click on a computer icon, we appear to access something hidden, yet what is actually revealed is sustained by a complex network of technical mediations, institutional practices, programming routines, usability norms, material infrastructures, and design decisions. This trivial gesture condenses an entanglement of relations that become invisible precisely because they operate with fluidity and stability. The double-click metaphor, therefore, exposes the tendency to naturalize technical systems as black boxes. ANT, in contrast, urges us to resist this reductionist impulse and to closely follow the concrete associations that shape sociotechnical reality.

From an ANT perspective, the double click operates as a methodological metaphor: to properly understand a phenomenon, one must move beyond the operational surface and investigate the multiple actants that enable its existence. Every click conceals a network, and sociotechnical analysis must render visible what has been erased through stabilization. In doing so, the researcher not only accesses the backstage of technologies but also denaturalizes the effects of obviousness and inevitability that surround sociotechnical systems in operation.

2.3 Postphenomenology and the Theory of Technological Mediation

Having outlined how ANT reformulates the “social” as networks of heterogeneous associations, this section turns to Postphenomenology and the Theory of Technological Mediation, which shift the focus to how concrete artifacts shape lived experience and ethical subjectivity.

Postphenomenology is a philosophical approach within the philosophy of technology that seeks to update and transform classical phenomenology in order to address the increasingly pervasive role of technology in everyday life. This approach was initiated by Don Ihde (1990) in response to the limitations of traditional readings that conceived technology either as a neutral tool or as an alienating force.

For Ihde, such interpretations fail to account for the ways in which artifacts genuinely participate in the constitution of human experience. Postphenomenology therefore starts

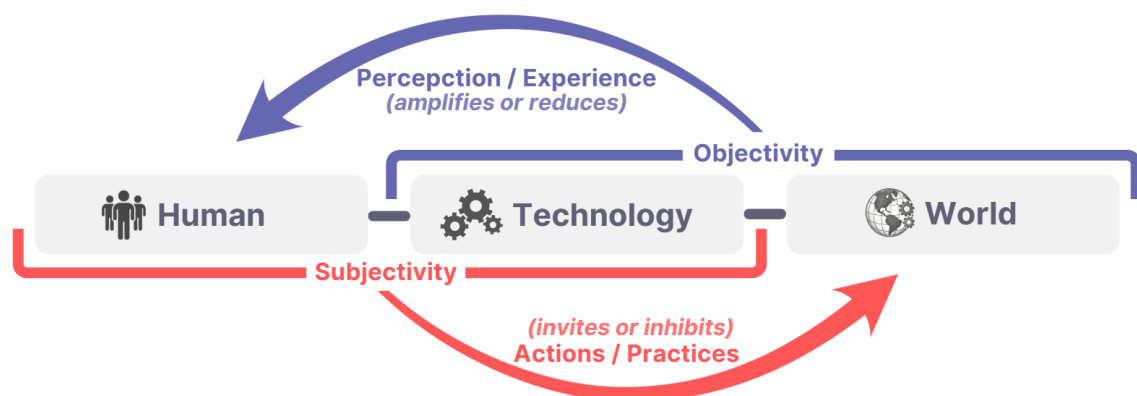
from the premise that technical artifacts directly influence how we perceive, act, and relate to the world. They do not merely “mediate”; they actively shape human-world relations (Ihde, 1990; Ihde, 1995).

Rather than focusing solely on abstract ideas about technology, Postphenomenology begins with the analysis of concrete technologies. This philosophy starts from things, examining how real objects such as microscopes, smartphones, or software systems participate in human experiences and social practices. Ihde proposed a typology of relations between humans and technology, including embodiment relations, in which an artifact becomes part of the bodily extension, as in the case of glasses or canes; hermeneutic relations, in which an artifact provides interpretations of the world, such as thermometers or medical examinations; alterity relations, in which we interact with technology as if it were another agent; and background relations, in which the artifact shapes the environment without direct interaction, such as ventilation systems.

Building on this philosophical foundation, Verbeek (2005a) proposed a broader systematization known as the Theory of Technological Mediation (TTM). This theory seeks to integrate philosophical analysis with empirical investigations into how concrete technologies operate in everyday life. In doing so, it aligns with STS (Rosenberger; Verbeek, 2015), but maintains a distinctive focus on lived experience and ethics. TTM shows that technical artifacts possess a form of agency. They shape social practices, moral decisions, interpretations of the world, and even the very ways in which humans understand themselves as moral subjects (Verbeek, 2005a; Verbeek, 2011).

In this sense, technology assumes a constitutive role in the ways human beings perceive, interpret, and act. It not only helps us do things but also helps us become a certain kind of being. Verbeek’s proposal distances itself from the idea that there is a subject (the human) and an object (the technology) that are separate and connected only by a functional mediation. Instead, he argues that subject and object are mutually constituted through mediation, and that technology helps shape the subject and the way the subject relates to the world (Verbeek, 2016; Verbeek, 2012). This systematization is represented in Figure 3.

Figure 3: Systematization of the Theory of Technological Mediation (TTM).



Source: Adapted from Hauser *et al.* (2018).

In the relation between humans and the world, technology operates along two main dimensions. The first dimension concerns experience and perception. Technology can

amplify or reduce certain aspects of the world, shaping how it is experienced (Hauser *et al.*, 2018). A thermometer, for example, amplifies the perception of temperature by converting it into an objective number, but it reduces other sensory dimensions of thermal experience. The second dimension concerns practices and actions. Technology can invite or inhibit certain behaviors. A button, for instance, may invite touch, while a physical barrier may inhibit access. The arrows labeled “amplify or reduce” and “invite or inhibit” illustrate how technology shapes both meaning-making and the orientation of conduct.

To structure the analysis of the complex interactions between humans and technology, Verbeek expanded Ihde’s work and identified seven types of technological mediation (Verbeek (2005a)).

2.3.1 Types of Technological Mediation

The types of technological mediation presented in Table 3 provide a framework for understanding how technologies mediate our relation with the world, affecting everything from perception to direct interaction. This framework makes it possible to map the diverse ways in which technology shapes human reality and how these relations both influence and are influenced by human and social practices.

Table 3: Verbeek’s Types of Relations with Symbolic Representation.

Type of Relation	Description	Symbolic Notation
Embodiment	Technology becomes part of the body as if it were an extension of it.	$(\text{human} - \text{technology}) \rightarrow \text{world}$
Hermeneutic	Technology helps interpret the world by making data or phenomena more understandable.	$\text{human} \rightarrow (\text{technology} - \text{world})$
Alterity	Technology is perceived as an “other” with which one interacts, almost as if it had personality.	$\text{human} \rightarrow \text{technology} (\text{world})$
Background	Technology operates discreetly, shaping the environment without calling attention to itself.	$\text{human} (\text{technology} / \text{world})$
Cyborg	Technology is integrated into the body, altering its capacities and identity.	$\text{human} / \text{technology} \rightarrow \text{world}$
Augmentation	Technology enhances human abilities such as strength, vision, or cognition.	$\text{embodiment} + \text{hermeneutic}$
Immersion	Technology creates immersive virtual environments that temporarily replace the real world.	$\text{human} \leftrightarrow \text{technology} / \text{world}$

Source: Author’s elaboration.

The **embodiment** relation occurs when technology integrates so seamlessly with the user’s body that it ceases to be perceived as an external object and becomes a transparent means of accessing the world. A typical example is a pair of glasses. We do not look at them; we look through them. In this relation, technology functions as an extension of the body.

In the **hermeneutic** relation, technology does not disappear from perception but operates instead as an interpretive mediator. Rather than extending the body, it translates the world into a readable form. A thermometer, for instance, does not display fever directly. It represents temperature on a scale that requires interpretation. The experience of the world is therefore mediated through a process of reading.

The **alterity** relation is characterized by engagement with technology as a quasi-other. Interactive devices such as Automated Teller Machines (ATMs), chatbots or

virtual assistants are treated as entities with which users establish a form of dialogue. Although these technologies do not possess subjectivity, they operate as mediators that request responses and structure user action.

The **background** relation refers to technologies that operate at the margins of experience, shaping contexts without requiring direct attention. Automated systems for climate control, lighting, or algorithmic filtering are examples of invisible mediations that nevertheless directly affect the conditions of action and perception.

Rosenberger e Verbeek (2015) also propose expanded forms of mediation that reflect more recent transformations in the ways technology becomes integrated with the body and the environment. The **cyborg** relation involves technologies that are physically integrated into the human body, such as neural implants or pacemakers. In these situations, the distinction between human and technology becomes blurred, and a hybrid form of subjectivity emerges that orients its intentionality toward the world in an integrated manner.

The **augmentation** relation occurs when technology enhances human capacities such as strength, vision, or cognition through a combination of an embodiment relation and a hermeneutic relation. A clear example is the industrial assistive exoskeleton used by workers in manufacturing environments. These devices are wearable and adjust to the body, moving with it in such a way that the user incorporates them into task execution. At the same time, they significantly increase the worker's muscular strength, allowing heavy objects to be lifted with less effort and reduced physical risk. This technological mediation reconfigures both action and the user's perception of their own body.

Finally, in the **immersion** relation, technological mediation occurs in the environment, but not in a silent or peripheral way as in background relations. In this case, the subject is actively enveloped by a technically constituted space whose responses and sensory transformations directly affect the user's experience. Immersion not only modulates perception but also configures new forms of action, emotion, and situational awareness. Unlike mediations that operate through portable or embodied devices, the immersion relation transforms the entire environment into a sensitive and responsive mediator, radically reconfiguring the way the subject inhabits and understands space. An example is a virtual reality environment in which the physical world is temporarily replaced by a simulated digital space.

2.3.2 Symbolic Notation of Technological Mediation

To support the understanding of the forms of mediation between humans, technologies, and the world, Verbeek (2005b) proposes a symbolic notation that represents the different possible relations within this interactional triangle. This notation aims to make visible the ways in which artifacts participate in the constitution of human experience and action, moving beyond the mere function or meaning of objects. The meaning of each symbol is presented below, based on its role in technological mediation:

- — (**dash**): indicates a functional connection or partial coupling between two elements. This notation appears, for example, in embodiment relations, in which technology enhances human action while still remaining distinguishable from the

user.

- $\rightarrow$ **(single arrow)**: indicates directional orientation or asymmetric mediation, in which one element channels or transforms the relation with another. This notation appears, for example, in hermeneutic relations, where the human is oriented toward the world through a technology that structures perception or interpretation.
- $\leftrightarrow$ **(double arrow)**: represents a reciprocal or co-influential relation between two elements. This notation appears, for example, in immersion experiences, where the human acts within a technical environment that responds dynamically to user actions.
- **() (parentheses)**: denote encapsulation or functional grouping of elements that operate together as a mediating unit. This notation appears, for example, in composite hermeneutic mediations, where technology and world are interpreted cohesively as an integrated whole.
- **/ (slash)**: indicates fusion or the collapse of boundaries between two elements, forming a hybrid entity. This notation appears, for example, in cyborg relations, in which human and technology become ontologically inseparable.
- **+ (plus)**: signals the composition or coexistence of multiple mediations within a single configuration. This notation appears, for example, in augmentation situations, where a single technology simultaneously articulates embodiment and hermeneutic forms of mediation.

2.4 Speculative Realism

When attempting to understand complex systems such as sociotechnical networks that integrate people and technologies, it is common to reduce them to their smallest components. However, this reductionist approach ignores the unique dynamics and behaviors that emerge from the interactions between components and from the broader context in which the system is situated.

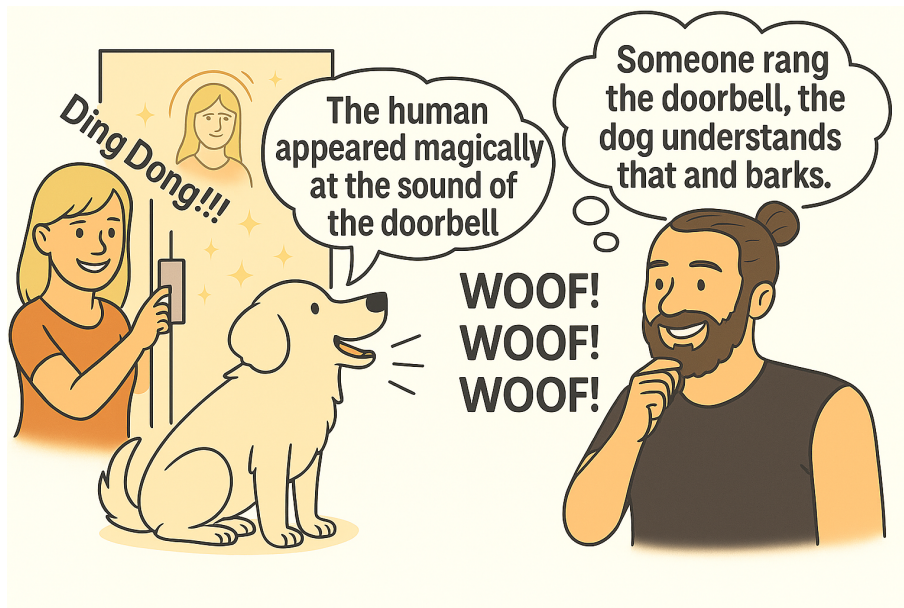
Immanuel Kant offers a critical lens on this idea of “total comprehension.” According to Kant, human knowledge is always conditioned by the structures of perception and cognition (Kant, 2020). We can access only the “phenomenal” world, meaning reality as it appears to us, and not the “noumenal” world, which refers to reality in itself. Although this imposes limits on knowledge, it still allows for a valid and practical understanding of phenomena, even if only a partial one (Haj-Bolouri *et al.*, 2024).

This Kantian distinction between what we can know and what remains inaccessible sets the stage for the critique formulated by Quentin Meillassoux, who revisits and radicalizes this epistemological problem by proposing the concept of “correlationism” (Meillassoux, 2006).

2.4.1 Correlationism

Quentin Meillassoux (2006) radicalizes this problem by naming “correlationism” the widespread philosophical assumption that we can know only the relation between thought and the world, never the world itself (Meyerson, 2023). Figure 4 provides an accessible illustration of the concept of correlationism.

Figure 4: Example of Correlationism.



Source: Author’s elaboration with support from ChatGPT 5.1.

When we observe the following scene in which a woman rings the doorbell, the dog barks, and the man interprets the situation, we are tempted to assume that the dog understood the event in the same way we do, as a causal relation between the sound and the presence of someone at the door. In doing so, we project our own structure of understanding onto the dog, as if the world were always intelligible through human categories. This assumption is precisely what characterizes correlationism.

Interestingly, Figure 4 performs a speculative exercise by attributing to the dog a form of cognition that escapes human rationality. By imagining that the dog might think something like “The human appeared magically with the sound of the doorbell,” the figure proposes an experience that differs from our own and is not based on causal reasoning. In doing so, the figure moves beyond the correlationist framework and suggests the possibility of modes of experiencing the real that fall outside human consciousness.

This imaginative opening, which seeks to conceive a reality accessible through other forms of agency or perception, is precisely what Meillassoux (2006) proposes as a philosophical task: to think being without necessarily binding it to thought.

Speculative Realism is a philosophical movement that emerges from Meillassoux’s critique of correlationism. He argues that it is possible to construct models of the real that are not conditioned by the mediation of consciousness. This approach rejects the

requirement of direct experience and defends the legitimacy of rational speculation about the objective conditions of the world, even without access to the “thing-in-itself.”

2.4.2 Object-Oriented Ontology

Object-Oriented Ontology (OOO), formulated by Graham Harman (2011), begins from a radical and straightforward principle: everything is an object. Rather than treating reality as something divided between conscious human beings on one side and passive, value-less “things” on the other, OOO proposes a flat ontology, that is, a way of thinking about being in which all entities share the same ontological level. This means that an ant, a microchip, a galaxy, a software system, an emotion, a phenomenon, an imagined unicorn, or even the flat earth as a mental concept are all real objects within this approach. They exist as entities with their own structure, even if in different ways. It does not matter whether they are material or immaterial, real or fictional, large or small; all of them are objects.

Thinking in terms of a flat ontology means breaking with much of the Western philosophical tradition, which tends to hierarchize entities by placing the human being at the center, or atoms as the fundamental base, or consciousness as the starting point of all inquiry. In OOO, there is no privileged center and no ultimate foundation. All objects, from the simplest to the most complex, exist in their own right and have the right to exist without needing to serve or appear to any other. This radical symmetry is what enables OOO to propose a new way of understanding reality.

However, the fact that all objects exist equally does not mean that everything is transparent or accessible. Quite the contrary. One of the central concepts in OOO is withdrawal, since objects never fully disclose themselves. Even when they interact with other objects, whether humans, machines, or animals, they are never revealed in their entirety. There is always an excess, a hidden core that resists the relation. This withdrawal is what defines the real object: that which remains, that which persists, and that which cannot be reduced to its appearances, functions, or parts.

Harman (2011) illustrates this using the example of the encounter between fire and cotton. When fire burns cotton, it does not access the cotton in its full ontological depth; it interacts only with certain sensible qualities of the cotton, such as its flammability, texture, and capacity for combustion. Fire does not “know” the history of the cotton, its industrial origin, its symbolic role in culture, or any other qualities that also compose what cotton is as a real object. This interaction is never total because objects are infinitely withdrawn, which means that there is always something left over, something untouched, even by the fire that consumes it. Even in an apparently destructive relation such as combustion, something of the cotton remains withdrawn and inaccessible, and the same is true of the fire. Conversely, when we interact with cotton, it reveals other properties, such as softness or lightness, but not its capacity for combustion.

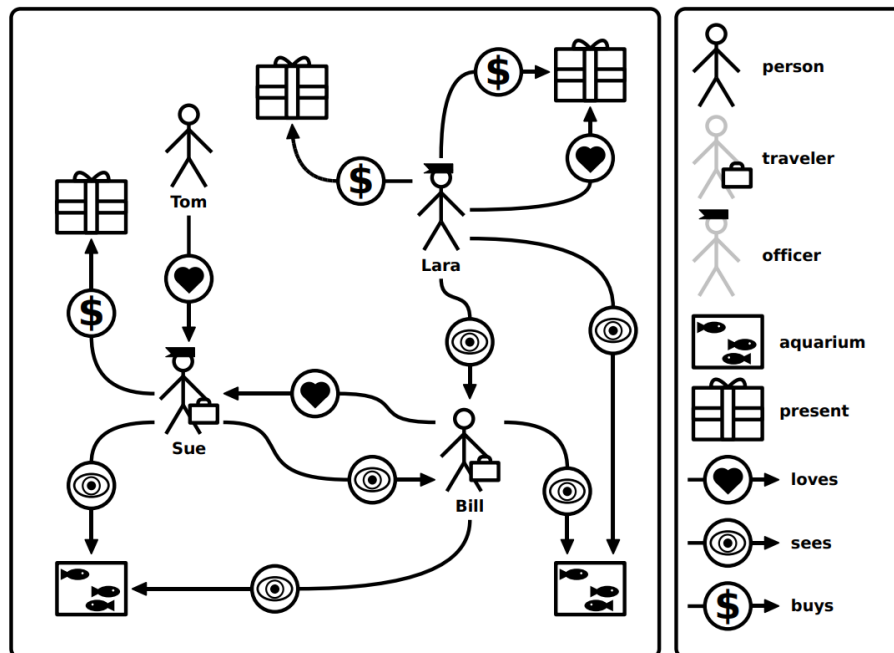
In OOO, this recognition of the object’s withdrawal is what distinguishes it from ANT, since objects do not need to be “in a network” in order to be real. This does not mean that relations are irrelevant, but rather that objects are not exhausted by the relations they establish. From this perspective, OOO holds that humans do not have direct access to the object itself. What we can grasp are only its sensual qualities, that is, what appears

in experience: the color of a screen, the warmth of the sun, the sound of a word, the operation of an algorithm.

2.4.3 Ontography

Ontography, as a concept, initially emerges in the work of Tobias Kuhn (2009) as a technical tool for precise graphical representation. It is a rigorous formalism used especially in industrial and computational documentation contexts, with the aim of representing relations between types and instances in controlled natural languages. The Kuhnian version of ontography does not seek to reflect on the meaning of being. Its concern is the functional clarity of connections: who sees whom, who buys what. Its focus is legibility, efficiency, and organization within a lean and diagrammatic model oriented toward the accuracy and intelligibility of structured microcosms, as illustrated in Figure 5.

Figure 5: Ontography of Relations among Actors, Objects, and Actions



Source: Kuhn (2009).

It is precisely this methodological containment that Ian Bogost (2012) decides to subvert. Revisiting the term, he proposes a philosophical overturning. Rather than functioning as a logical device of ordering, ontography becomes, in his approach, a speculative strategy for revealing the unruly profusion of the real, seeking to grasp the essence of entities without hierarchies, without explanations, without purposes, as an inventory of multiple cohabitants.

This radical reorientation seeks to break with correlationism by presenting not collections organized through curatorial categories, but rather chaotic accumulations that resist any attempt at classification. It abandons causal logic in favor of expressive forms that evoke wonder: seemingly arbitrary lists that spark the imagination (a fish, a weapon, a shard of glass); photographic images that suspend any hierarchy among elements (a

plate, a Styrofoam box, a shadow cast on a table); or games that materialize improbable ontological combinations (a helicopter in a lake full of piranhas). At the same time, by placing heterogeneous objects side by side without hierarchy, ontography resonates with the notion of flat ontology, which distributes entities symmetrically on a single plane of existence.

In this sense, ontography does not seek to order the world but to marvel at it. It aligns with an aesthetics of surprise, in which the world reveals itself in its own density, without the organizing mediation of human subjectivity. The human, in this context, is decentered. There is no longer a sovereign subject that arranges the world, but rather just one entity among many that co-inhabit an entangled reality.

2.5 Agential Realism

Agential Realism is an ethico-onto-epistemological approach developed by Karen Barad (2007)⁴, whose roots lie both in feminist epistemology⁵ and in Niels Bohr's principles of quantum physics. This framework offers a radical alternative to philosophical traditions grounded in representationalism, which conceive knowledge as a neutral and accurate description of an external and preexisting reality.

In contrast, Agential Realism proposes that knowing is a performative act in which discursive-material practices do not merely describe the world but actively constitute it. Rather than reflecting a given world, the act of knowing produces specific, situated, and contingent realities through materializing practices that entangle matter and meaning from the very beginning. Reality, in this sense, is not something that simply reveals itself but something that is enacted. Figure 6 illustrates this contrast between representationalist and performative paradigms.

The following subsections examine the central concepts of Agential Realism in greater depth, including materiality, intra-action, agential cuts, and the diffractive model.

2.5.1 Materiality

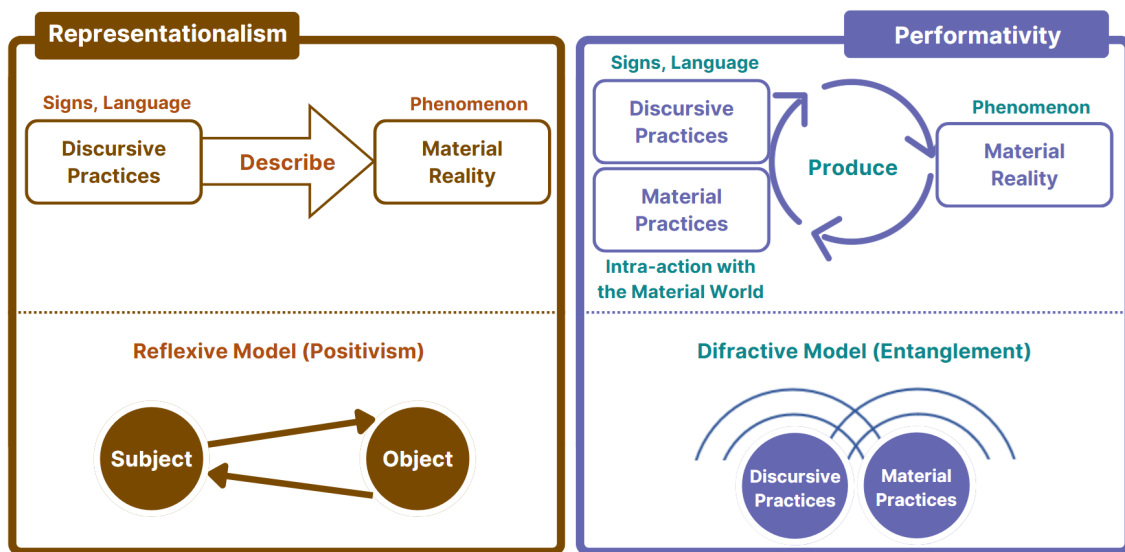
In representationalism, material reality is treated as something that exists independently and is merely described by language. Discursive practices operate as mediators that depict an already given world in which subject and object are defined in advance.

In Agential Realism, materiality is not a passive background, an essential substance, or something that can be simply described. It is an active and dynamic process in which matter and meaning are co-constituted through specific practices. Rather than an essence that precedes experience, matter is conceived as intra-actively produced, that is, as

⁴Karen Barad holds a PhD in Theoretical Physics from Stony Brook University, with specialization in quantum mechanics.

⁵Feminist epistemology is a critical approach to traditional epistemology that examines how gender influences the production of knowledge. It challenges the supposed objectivity, neutrality, and universality of scientific inquiry, showing how these categories often reproduce masculine and Eurocentric standpoints (Haraway, 2013b).

Figure 6: Comparison between the Representationalist Model and Performativity



Source: Author's elaboration.

something that makes a difference in the world and acts alongside discourses, instruments, bodies, and spaces.

This perspective begins by breaking with the traditional view that opposes language and reality, word and thing, culture and nature, subject and object. These separations are artificial and politically charged (Haraway, 2013a). Matter matters because it participates in the production of the world. All knowledge, all practice, and all observation involve material-discursive practices. These practices do not merely represent the real; they perform it.

This means that the conditions that make something visible, measurable, thinkable, or even existent are always configured through an entanglement of material dimensions (such as techniques, apparatuses, and bodies) and discursive dimensions (such as categories, classifications, and norms). Matter is not simply “there”; it emerges relationally within the phenomena that constitute it.

2.5.2 Diffractive Method

In the traditional model of understanding the world, as described by Barad (2007), science and language are conceived as neutral instruments intended to mirror an external, objective, and preexisting reality. This is a representational mode of knowing that describes the world as something separate from the subject who observes it.

In Agential Realism, by contrast, knowledge is not a mere representation but an act that actively participates in the constitution of the world. Knowledge is therefore performative, because it involves practices that produce the very real that they seek to understand. The observer is an integral part of the phenomenon, and their choices, practices, and instruments influence and co-produce what will be recognized as reality.

The diffractive method thus offers an alternative to the mirror metaphor. Rather than

reflecting the world, knowledge is understood as an intra-active interference pattern formed through encounters among material and discursive practices. Intra-actions propagate like waves that intersect, interfere, and generate new patterns, sometimes reinforcing one another and sometimes canceling each other out.

An example can be seen in the diffractive analysis of a speculative design workshop. Participants' statements, the tools they used, and the researcher's interpretations become entangled and mutually affect one another, producing new understandings of the investigated phenomenon rather than merely describing it.

2.5.3 Intra-Action

In Agential Realism, the world is not composed of separate entities that then interact, but of intra-active phenomena. One of its central concepts is intra-action. Unlike interaction, which presupposes two or more preexisting elements, intra-action indicates that the components of a phenomenon emerge together, mutually constituting one another within the very relational act.

Phenomena are therefore transient and dynamic, manifesting through interference patterns that reflect the ways material and discursive practices become entangled in situated contexts. Subject, object, apparatus, data, and context do not preexist the relation; they are local and contingent effects of intra-action.

Agency, in this framing, is not an individual property but a distributed capacity that emerges relationally from the intra-actions through which the world comes into being. There is therefore no human agency that dominates matter, but an agency that manifests within the very intra-active arrangements that materialize the real in situated ways.

2.5.4 Agential Cuts and Apparatuses

Because phenomenal materiality is intra-relational, unstable, and contingent, the phenomenon takes shape through agential cuts, which are material-discursive practices enacted within intra-actions. Thinking the phenomenon therefore requires attending to the ways waves of matter, meaning, and action propagate, intersect, and interfere with one another, producing complex patterns marked by intensifications and silences.

An agential cut does not reveal a previously structured world; it enacts a localized delineation within the entangled relations that constitute a phenomenon. These cuts are carried out by apparatuses, understood not as conventional technical instruments but as material-discursive constellations composed of practices, norms, languages, devices, bodies, and technical arrangements that shape what can emerge as subject, object, or context.

In this sense, the apparatus is a stabilized material-discursive practice that not only differentiates but also constitutes the elements of the phenomenon. It participates actively in the production of the real rather than simply mediating it.

When an agential cut is enacted through the apparatus, it temporarily delimits certain relations, allowing something to manifest as an "object," an "instrument," or "data." These

categories, however, are not intrinsic properties of things but local and situated effects of intra-active practices.

2.5.5 Ethics and Responsibility

In Agential Realism, ethics is not a sphere separate from ontology or epistemology but a constitutive dimension of reality itself. Every intra-action involves agential cuts that produce specific materializations of the world while simultaneously excluding other possibilities. In this process, decisions are made about what counts as real, who or what matters, and what will be silenced or disregarded.

Unlike ethical conceptions based on autonomous subjects and external values, responsibility in Agential Realism is endogenous. It emerges from within the very intra-actions that constitute phenomena. There is no isolated moral agent who later responds to the world; rather, there is a responsivity that coexists with the very emergence of the world, since acts of differentiation already carry ethical implications.

This dimension is referred to as the “Ethics of Differential Responsiveness” (Barad, 2007, pp. 380), in which we are implicated in the consequences of the materializations we help bring about. To be responsible, in this context, is to remain attentive to the exclusions enacted through agential cuts and to the realities we fail to make possible.

Justice, therefore, is neither an external abstraction nor a universal norm, but an embodied practice. In this context, the term “embodied” means that ethics is manifested in the concrete materializations of phenomena, in the real effects that produce possible and impossible worlds. It is not merely a matter of thinking about what is just, but of acting in the world with attention to the onto-epistemological consequences of each practice.

2.6 Speculative Design

All design practices, at their core, shape the future. However, design approaches are often confusing and difficult to understand, since they vary widely in their orientations and goals. To organize this diversity, this dissertation proposes a spectrum that positions design orientations between poles ranging from restricted to unrestricted and from past-oriented to future-oriented.

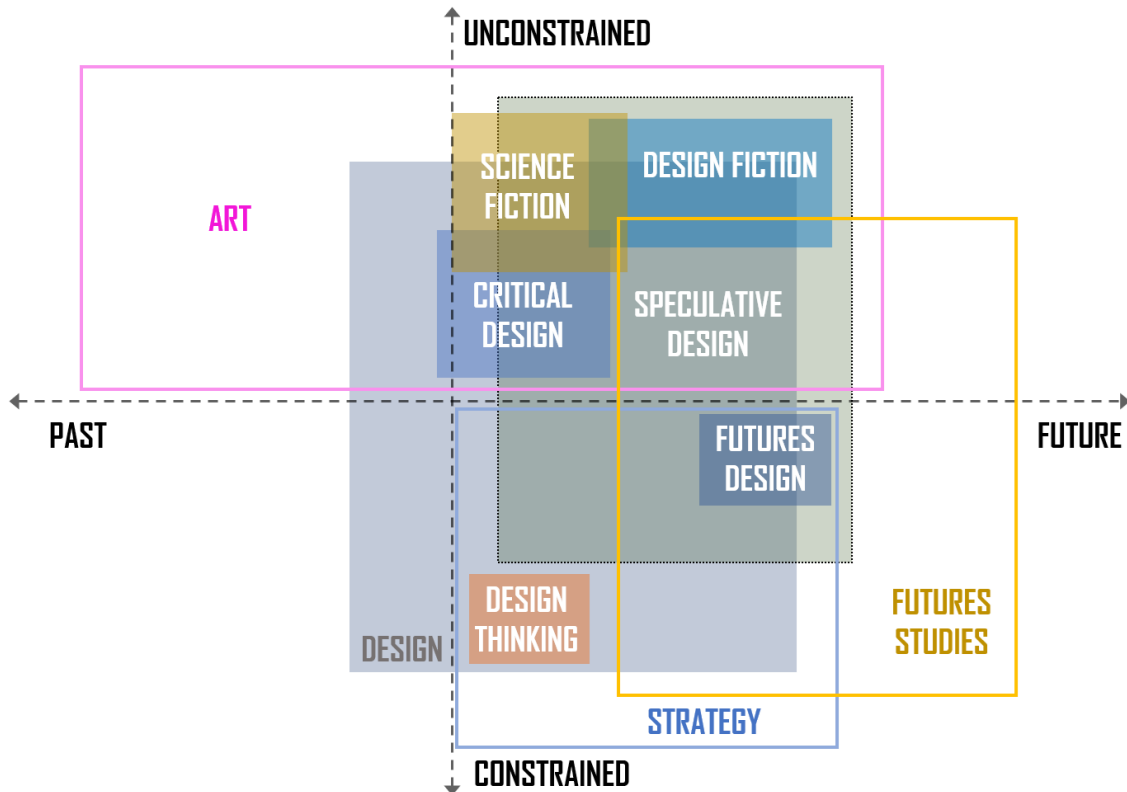
2.6.1 Future-Oriented Design

Future-oriented design is an approach that seeks to move beyond the solution of immediate needs. Its goal is to support the creation of plausible visions and future scenarios in order to guide present decisions and stimulate innovation (Mozuni; Jonas, 2017). Instead of limiting itself to the here and now, this field employs methods of foresight and anticipation to explore emerging possibilities, trends, and challenges (Blauvelt, 2019).

An important characteristic of this domain is the diversity of methods and tools

available. The boundaries between them are not rigid, as different practices overlap, interact, and evolve together (Mitrović *et al.*, 2021). This dynamic makes future-oriented design a field in constant revision, in which roles, goals, and methods are continuously reassessed. Figure 7 illustrates how different perspectives connect within this ecosystem.

Figure 7: Interconnection among Design Approaches within a Future-Oriented Perspective



Source: Author's elaboration. Adapted from (epmid 2024)⁶

In Figure 7, the vertical axis labeled “future” and “past” should not be understood as a literal timeline. It indicates whether the emphasis of each approach lies in consolidated practices or in future possibilities.

Within this interdisciplinary space, several areas converge. Futures Studies provide systematic methods for organizing scenarios and trends. Strategy connects these visions to action plans and practical objectives. Science Fiction expands the horizon by proposing imaginative futures, while Art fosters reflection by exploring the aesthetic and expressive dimensions of those futures (Wakkary *et al.*, 2022). Finally, Speculative Design transforms these futures into tangible objects, interfaces, and experiences, enabling interaction with the possibilities they envision.

Although Future-Oriented Design opens pathways for thinking about possibilities beyond immediate needs, many of its practices still assume the human as the starting point and primary beneficiary. more-than-human design (MtHD) (Giaccardi *et al.*, 2025; Nicenboim *et al.*, 2024) emerges as a radical response to the limitations of the traditional

⁶epmid: <https://epmid.com/Mapping-Speculative-Design>

human-centered paradigm, offering a critical lens that is indispensable for addressing contemporary and emerging challenges, such as transhumanism, which advocates overcoming human biological limits through biotechnologies, and posthumanism, which deconstructs the ontological and moral centrality of the human (Key *et al.*, 2022).

2.6.2 Theoretical Perspectives in Speculative Design

What defines Speculative Design is its capacity to explore possibilities and provoke change through the creation of a critical vision of the technological impacts on society. This approach incorporates several theoretical perspectives that enrich its applicability and depth, forming a mosaic of interconnected practices that fuel speculation about the future.

Speculative Design is deeply influenced by **Critical Theory** (Bardzell; Bardzell, 2013), particularly by the principles of the Frankfurt School, which provide tools for analyzing and questioning dominant social, cultural, and technological structures (Malpass, 2019). This theoretical foundation enables Speculative Design to create artifacts that transcend utilitarian functions and promote ethical and social reflection on technological innovations. By adopting a critical stance, Speculative Design challenges social norms and invites audiences to imagine alternatives to established systems of power and consumption.

Moreover, it advances a critique of the status quo (Malpass, 2019), using design as a political practice that contests norms of consumption and production and highlights how technologies, when shaped by capitalist interests, often reinforce social and economic inequalities (Forlano; Halpern, 2023). In this way, Speculative Design offers visions of more equitable and sustainable futures (Pasa; Sinni, 2024), as exemplified in Rafael *et al.* (2023)'s study on surveillance capitalism (Zuboff, 2019).

Fiction, inspired by **Design Fiction**, is an essential component of Speculative Design (Loutfi; Siqueira, 2024). Dunne e Raby (2024) employ speculative narratives to create prototypes that function more as thought experiments than as practical solutions, enabling the exploration of alternative futures. Fiction thus becomes an epistemological tool that expands the understanding of the implications of emerging technologies. Through the overlap between Design Fiction, Critical Design, and Speculative Design, it becomes possible to combine artistic imagination with critical analysis, facilitating the exploration of speculative scenarios and anticipating potential social and ethical developments.

Speculative Design is strongly supported by **Futures Studies**, which provide methods for analyzing trends, uncertainties, and potential scenarios (Candy; Dunagan, 2017, pp. 136-153). These studies enable Speculative Design to extrapolate the long-term effects of technologies and to create plausible futures that highlight ethical considerations and potential unintended consequences. The goal is not to predict the future but to foster critical dialogue about the trajectories of technological development (Milojević; Inayatullah, 2015, pp. 151-162).

Although Speculative Design can be explored as an artistic and unrestricted approach that imagines unusual scenarios and structures to provoke reflection and challenge assumptions, it also draws on strategic foresight and anticipatory projection (Hines *et al.*,

2006). By grounding itself in Futures Studies, Speculative Design seeks to inform present-day decisions by visualizing futures that can consciously and critically guide technological development.

2.6.3 Tension Patterns in Speculative Design

The theoretical perspectives presented here ground the main characteristics of Speculative Design. Critical Theory questions dominant structures and proposes more just futures, while fiction, inspired by Design Fiction, explores alternative scenarios and the impacts of emerging technologies. Futures Studies, in turn, provide tools for projecting long-term scenarios and assessing their social and ethical implications. Indeed, as Helgason *et al.* (2021) argues, Speculative Design stands out as an innovative approach by integrating fields such as art, design, computer science, and the social sciences, enabling the analysis of complex issues and preparing participants for future challenges. Speculative Design also cultivates practical skills, such as communication and project design, as well as critical skills, such as reflective and systemic thinking, encouraging deeper analyses of the social and ethical impacts of technologies.

These influences make Speculative Design multidisciplinary, committed to social and environmental justice, and oriented toward both process and outcomes. Moreover, tension patterns (Encinas *et al.*, 2023; Mitrović *et al.*, 2021) emerge as key elements that reflect interactions between opposing tendencies, such as inclusion versus exclusion or a focus on process versus the final product, as presented in Table 4.

Table 4: Tension Patterns in Speculative Design

Tension	Spectrum	Description
Human Exclusion	From exclusive to inclusive	Addresses who is included or excluded in the design process, especially with regard to marginalized groups.
Engagement	From witness to participant	Considers the level of public involvement, which may range from passive observation to active participation.
Use	From narrative to practical	Explores whether the speculative object will be interpreted as a reflective provocation or as a functional product.
Gain	From knowledge to commercial value	Analyzes who benefits from the design, such as through the production of reflection, social impact, or profit.
Perspective	From local to global	Assesses the viewpoint adopted, taking into account cultural, social, and economic differences.
Time	From past to future	Investigates whether the design retrieves the past, describes the present, or projects the future.
Non-Human Inclusion	From human-centered to more-than-human	Examines how ecological elements and non-human species are integrated into the proposal.
Completion	From sketch to finalized product	Considers whether the design is at a conceptual stage or already resolved as a prototype or product.

Source: Author's elaboration.

These patterns serve as guides for navigating the complexities of Speculative Design, shaping project development and helping designers assess whether the outcomes align with the initial expectations and objectives.

The **Human Exclusion** pattern addresses the exclusion of voices, bodies, and perspectives within speculative practices. Mitrović *et al.* (2021) argue that, despite the

emancipatory potential of Speculative Design, it often reproduces structural exclusions related to race, gender, class, or geographic origin. The scope of this tension lies between the “human” and “humanity” as a universalizing abstraction. Speculative projects tend to speak “on behalf of humanity,” yet they frequently silence those who have been historically marginalized. The challenge here is to construct speculative futures that acknowledge and include these absent voices and existences.

An example can be found in projects that adopt decolonial epistemologies and afrofuturist approaches, such as Black Future Heritage Spaces⁷, which used Speculative Design as a tool to imagine desirable futures that value and preserve Black cultural heritage. In this project, physical artifacts were created to represent objects from these envisioned worlds.

The **Engagement** pattern defines the level of public participation, which ranges from the position of the spectator, who observes in a distanced and reflective manner, to that of the participant, who interacts, co-creates, or performs with the artifact. Mitrović *et al.* (2021) emphasize that engagement should not be understood as merely interactive but as something capable of generating subjective and social transformations. Rather than simply observing an alternative future, the participant is invited to inhabit and reconfigure it. The degree of engagement shapes the ethical and affective experience of the project. Encinas *et al.* (2023) further notes that even in activities that adopt participatory methodologies, such as card games or speculative narratives, students do not always become fully engaged participants.

The **Use** pattern explores the tension between artifacts conceived as speculative narratives intended to prompt reflection and those that function as practical, interactive products. The risk identified is that, by attempting to solve a problem through a “product,” the project may lose its critical ambiguity. Conversely, by distancing itself entirely from functionality, it may be perceived as irrelevant or empty. Mitrović *et al.* (2021) suggest that a balance is possible: speculative objects can be simultaneously critical and functional, depending on the strategy adopted.

The **Gain** pattern invites reflection on who benefits from the proposed speculation. This tension involves both material gains, such as monetization and efficiency, and immaterial gains, such as awareness, critical learning, or symbolic reconfiguration. Projects that prioritize only economic benefits tend to diminish the critical potential of Speculative Design. Mitrović *et al.* (2021) argue for the value of benefits that cannot be quantified, which are often invisible yet deeply transformative, such as the capacity to imagine other worlds and to cultivate empathy, indignation, or hope.

The **Perspective** tension examines the point of view from which the future is narrated. It contrasts dominant perspectives, which are often Western, white, male, cis, and technocratic, with counter-hegemonic, situated, and plural visions. Mitrović *et al.* (2021) emphasize that speculation, even when critical, can become colonizing if it does not question the project’s position of enunciation. This tension therefore requires interrogation of questions such as: Who is speaking? For whom? With which assumptions? In this sense, Encinas *et al.* (2023) argue that this tension shapes how the project relates to its context and to the publics it affects. Blauvelt (2020) analyze how

⁷ Black Future Heritage Spaces: <https://speculativeedu.eu/case-study-black-future-heritage-spaces/>

visual representations of the future, frequently promoted in design practices, can contribute to the exclusion of diverse voices and perspectives. The concept of “defuturing” refers to the ways in which certain design practices contribute to the negation or elimination of possible futures, particularly by perpetuating dominant worldviews that marginalize other forms of knowledge and existence.

The **Time** pattern concerns the relationship between past, present, and future, examining whether the design preserves traditions or projects future scenarios. The choice of temporal horizon affects both the reception and the impact of the project. Futures that are too distant may appear irrelevant or inaccessible, while futures that are too near may be mistaken for predictions. [Mitrović et al. \(2021\)](#) argue for the strategic use of temporality and emphasize that futures should be provocative yet relatable, since their strength lies in their capacity to influence the present. [Encinas et al. \(2023\)](#) note that although every speculative project is situated in the present, meaning the moment in which it is created and from which it communicates particular aspects, it may thematically address the past through counterfactual narratives, the present through alternative presents, or the future through speculative visions.

The **Non-Human Inclusion** pattern highlights the presence or absence of non-human agents, including technologies, environments, and artificial or natural entities within speculative projects. It concerns the tension between human-centered design and more-than-human approaches ([Coulton; Lindley, 2019](#); [Stead et al., 2022](#)). Non-human inclusion is not merely decorative but epistemological, since it transforms how problems are defined and how solutions are conceived. By granting agency to robots, algorithms, animals, or ecosystems, projects invite a reconfiguration of the boundaries between nature, culture, and technology, which constitutes a deeply ethical and political gesture ([Coulton et al., 2024](#)).

Finally, the **Completion** pattern considers the degree of completeness of the design, whether it takes the form of an initial sketch, a prototype, or a finalized product, and helps determine where effort should be focused. On the one hand, fully developed and visually polished artifacts can communicate clarity and sophistication. On the other hand, unfinished and open-ended projects stimulate imagination and interpretive engagement. The tension lies between control and ambiguity. [Mitrović et al. \(2021\)](#) argue that the value of Speculative Design often resides in openness, meaning its capacity to generate multiple interpretations and reactions, including contradictory ones. Incompleteness is not a flaw but a deliberate strategy to broaden the spectrum of possible meanings.

2.6.4 Speculative Design Tools

The application of Speculative Design practices is supported by a growing set of toolkits developed to guide designers through speculative processes. These toolkits vary in their approaches: some operate as independent initiatives that are not tied to any particular methodology or framework, while others are created to support established Speculative Design methodologies by providing a more structured and directed workflow. The study by [Chivukula et al. \(2021\)](#) identifies more than 63 design methods applicable to Speculative Design, highlighting the breadth and diversity of available methods.

2.6.4.1 Standalone Toolkits

Standalone toolkits that operate outside specific Speculative Design frameworks offer designers greater flexibility and autonomy. Among these, **Discovery Sessions**⁸ stand out for their use of image cards to identify opportunities and challenges, encouraging a more imaginative engagement with possible futures. Another widely adopted resource is **Cover Story**⁹, which invites participants to create fictional magazine covers as a means of envisioning ideal futures and articulating long-term goals. Complementing these methods, the **Futures Wheel**¹⁰ supports the mapping of cascading consequences resulting from technological innovations.

The **Envisioning Radar**¹¹ visually maps technological innovations and their potential impacts, fostering a systemic understanding of how emerging technologies interrelate. Likewise, the **Digital Ethics Compass**¹² offers a human-centered guide for formulating ethical questions, helping designers avoid recurrent pitfalls in technosocial projects.

Some toolkits adopt card-based formats. The **Tarot Cards of Tech**¹³ encourage critical reflection on the ethical and social implications of technology, while **Trend Cards**¹⁴ map emerging trends and driving forces that shape speculative futures.

The incorporation of Generative Artificial Intelligence (GenAI) models such as ChatGPT, Gemini, and other emerging platforms is also becoming increasingly prevalent in speculative design practices. These systems support both the construction of fictional narratives and the structuring of future scenarios, frequently acting as co-authors in the development of sociotechnical imaginaries. Beyond these broader applications, new tools have been created specifically for speculative design, such as the **Future Scenario Maker**¹⁵, which provides automated guidance for the structured creation of speculative scenarios.

2.6.4.2 Toolkits for Frameworks and Methodologies

In addition to standalone toolkits, there are those developed within the context of specific design frameworks or methodologies. For example, the **Future Vision Generating Toolkits** (Fu; Zhu, 2020) is a structured kit that guides the creation of speculative scenarios for smart cities, directing the design of technological innovations with a future-oriented focus.

The **Problem-Driven Iterative Adaptation** (PDIA) toolkit (SAMJI; KAPOOR, 2022) offers a step-by-step approach to addressing complex problems by breaking issues down to their root causes, identifying entry points, and exploring contextual solutions.

The **Building Utopias** Toolkit (Bray *et al.*, 2022) stands out as a toolkit developed with an afrofuturist orientation, aimed at supporting community-led design practices,

⁸<https://www.bromfordlab.com/lab-diary/2018/2/12/discovery-sessions-a-reflection>

⁹<https://gamestorming.com/cover-story/>

¹⁰<https://www.mindtools.com/a3w9aym/the-futures-wheel>

¹¹<https://radar.envisioning.io/?pg=home>

¹²<https://ddc.dk/tools/toolkit-the-digital-ethics-compass/#compass>

¹³<https://www.artefactgroup.com/resources/the-tarot-cards-of-tech/>

¹⁴<https://www.wedesignthinking.com/en/tools/trend-cards/>

¹⁵<https://ai.boardofinnovation.com/future-scenario-maker>

particularly within groups that have been historically marginalized.

Finally, **the Social is the Thing** (SITT) model (Wahlin; Blomkamp, 2022) combines approaches such as Design Thinking, Co-Design, and the Public Policy Design Arc from the Harvard Kennedy School, adapted for strategic planning in local governments, with the goal of democratizing design methods and increasing community participation.

2.7 Final Considerations of the Chapter

This chapter presented the main approaches that constitute Entanglement Theories: ANT, Postphenomenology, Speculative Realism, and Agential Realism. These theories offer alternative perspectives for understanding sociotechnical phenomena based on a relational and non-dualist ontology. They share a rejection of the modern separation between subject and object, nature and culture, language and matter, and propose that the world emerges from entanglements among practices, materials, meanings, and human and non-human agencies.

Each approach contributes specific conceptual elements. ANT highlights distributed action and symmetric agency between humans and non-humans, proposing a sociology of associations. Postphenomenology and the Theory of Technological Mediation demonstrate how technologies shape experience and configure relations between humans and the world through specific mediations. Speculative Realism breaks with correlationism by defending the existence of a reality that is independent of human cognition, while OOO proposes a flat ontology in which all entities possess their own reality. Agential Realism introduces a performative and diffractive model of the constitution of the real, integrating ontology, epistemology, and ethics, with direct implications for responsibility in materialization processes.

Although these theories have diverse origins, they have been progressively incorporated into the field of Computing, especially in areas such as HCI, systems design, artificial intelligence, and critical technology studies. However, this incorporation still occurs unevenly and, in many cases, without systematic integration.

In this context, Speculative Design emerges as a practice with the potential to productively incorporate these contributions. By shifting the focus of traditional design, which is centered on solving immediate problems, toward imagining possible futures and reflecting on ethical, political, and sociotechnical implications, Speculative Design directly benefits from the insights offered by these approaches. Entanglement Theories expand its capacity to engage with complex systems, recognize distributed agencies, and adopt non-anthropocentric ontologies in the projection of futures.

3. Literature Review

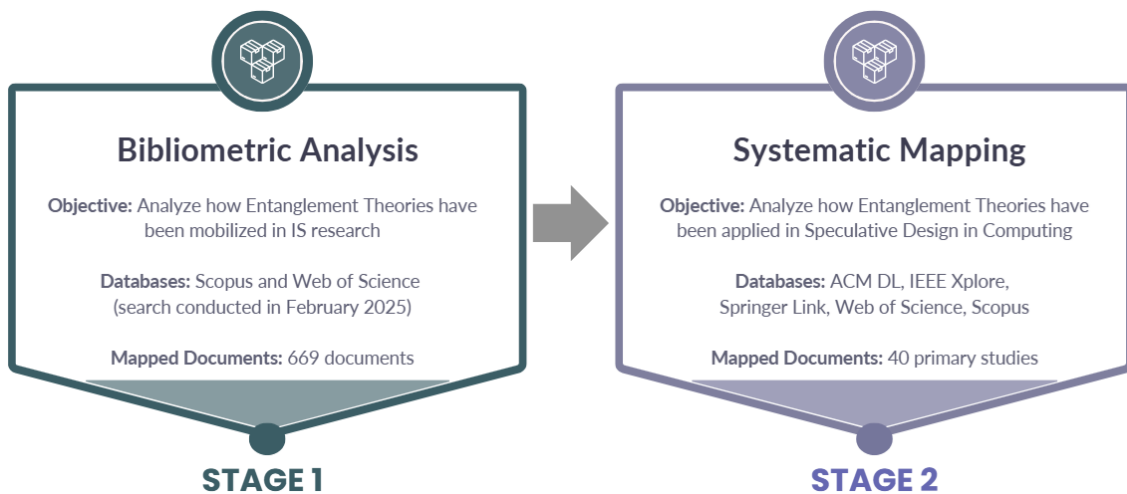
This chapter deepens the study of the Entanglement Theories and Speculative Design through a systematic investigation of the literature. Its goal is to map the state of the art, understand how different theoretical currents have been mobilized in Computing, and, in particular, analyze how these theories have been engaging (or not) with speculative design approaches.

The investigation is conducted through two complementary strategies: a bibliometric analysis followed by a systematic literature mapping (SLM). Together, these strategies provide an overview of the field and show that, although relevant intersections exist between Entanglement Theories and future-oriented design, these convergences remain largely underexplored when considered together. This finding reinforces the relevance of this dissertation's contribution and prepares the ground for the framework presented in the following chapter.

3.1 Contextualization

The consolidation of a robust theoretical foundation on the Entanglement Theories within the field of Computing, particularly their articulation with Speculative Design, requires a methodological approach that goes beyond traditional literature reviews. Given the conceptual dispersion, epistemological fragmentation, and lack of methodological consensus observed in preliminary studies, a dual literature-review procedure was adopted, combining Bibliometric Analysis and SLM, as illustrated in Figure 8.

Figure 8: Stages of the literature review process.



Source: Author's elaboration.

The choice of distinct scopes for each stage stems from a strategic difference in

objectives. The bibliometric analysis was conducted within the domain of IS, a field in which the Entanglement Theories have been historically mobilized and where there is a sufficiently robust body of publications to identify collaboration patterns, conceptual trends, and epistemological gaps. The SLM, in turn, focused on the field of Computing, with the aim of examining how these theories have been appropriated within Speculative Design, as well as in pedagogical, infrastructural, software development, and other related practices. This delimitation provides, on the one hand, a panoramic view of the theoretical debate in IS and, on the other, a situated analysis of applications in Computing, both of which are essential for supporting the objectives of this dissertation.

The bibliometric analysis follows principles of scientometrics (Hassan; Loebbecke, 2010), understood as the quantitative and qualitative study of scientific production and communication. This approach makes it possible to identify patterns, relationships, and trends in the literature on Entanglement Theories in IS. The investigation revealed how these theories have been mobilized over the past decades. The data show a trajectory of growth, although marked by significant challenges such as the low rate of international collaboration (only 4.63%) and the scarcity of integrative reviews. The results include thematic visualizations, co-occurrence networks, citation evolution, authorship patterns, and transnational collaborations.

The SLM stage was conducted with a qualitative and exploratory focus, aiming to understand how these theories have been appropriated, combined, and operationalized by studies that employ speculative practices in the field of Computing. The analysis of the 40 selected studies, following a protocol adapted from SEGRESS (Kitchenham *et al.*, 2023), revealed both innovative conceptual appropriations and recurring epistemological gaps, such as the superficial or merely illustrative use of theoretical approaches.

The complementarity of the two stages makes it possible to outline a more comprehensive picture of the state of the art and serves a strategic purpose: to ground the development of the framework that integrates the Entanglement Theories with Speculative Design (the central proposal of this dissertation), to clarify the relevance of the Entanglement Theories for speculative practices, and to guide the design of the Speculative Design tools associated with the framework.

3.2 Bibliometric Analysis

The Bibliometric Analysis was inspired by the framework proposed by Öztürk *et al.* (2024). A summarized version of the results is presented here in order to avoid overwhelming the reader with excessive detail. Complete information, including methodological descriptions, visualizations, and extended analyses, can be found in Appendix A. Part of this material has also been consolidated into an article submitted to a high-impact international journal.

In this condensed version, the emphasis is placed on the main findings, particularly regarding the historical trajectory, the impact, and the collaboration networks surrounding these theories. The analysis examined aspects such as the volume and type of publications over time, academic recognition through citations, the role of central authors and their connections, and the convergence among theoretical references, influential authors, and

recurring keywords. Additionally, a semantic analysis was conducted to identify thematic clusters and theoretical approaches that have gained prominence in recent debates.

3.2.1 Research Method

Studies published in English were collected, and the search strategy included both the central terms of these theories and their extensions, incorporating expressions such as “Object-Oriented Ontology” and “Theory of Technological Mediation.” Within the IS domain, terms representative of its thematic diversity were included, ranging from IT infrastructure and governance to sociotechnical design, HCI, data science, and artificial intelligence. This choice made it possible to capture approaches that span system development as well as the ethical and organizational implications of technology.

The bibliometric mapping was conducted in four distinct phases, beginning in September 2023 and updated periodically to follow the evolution of the literature. The final update occurred on 10 February 2025, when the complete dataset for this analysis was consolidated. Searches were performed in the Scopus and Web of Science databases. Document selection followed a structured three-stage process adapted from the model proposed by [Page et al. \(2021\)](#).

In **stage 1**, a preliminary selection was conducted in the Scopus and Web of Science databases using search strings designed to capture the diversity of scientific publications related to the Entanglement Theories in IS and related fields. In **stage 2**, thematic filters specific to both databases were applied in order to restrict the results to the scope of IS and adjacent areas. The selected documents were then organized and processed through an evaluation of titles, abstracts, languages, and publication venues. An R script (see Appendix [B](#)) was developed to consolidate the data retrieved from the selected databases. Finally, in **stage 3**, additional documents were included and incomplete records were removed from the consolidated dataset, resulting in a total of 669 documents, which were exported to the Biblioshiny tool, in which descriptive and exploratory analyses of the bibliometric data were conducted.

3.2.2 Data Analysis

The data analysis of the Bibliometric Study sought to understand the evolution, impact, and thematic configuration of Entanglement Theories in IS. The first stage identified temporal publication trends, document types, and patterns of authorship. The subsequent stage examined academic impact by considering the average number of citations and the most influential articles. The authorship analysis mapped the main researchers and their collaboration networks using metrics such as citations normalized per year. The investigation also connected the main theoretical references to authors and keywords through three-dimensional visualizations. Finally, thematic evolution was explored through word clouds, co-occurrence networks, and temporal analyses.

3.2.3 Results and Discussion of the Bibliometric Analysis

The bibliometric analysis of the use of Entanglement Theories in IS reveals three central findings. First, it highlights the historical centrality of ANT as the predominant reference. Second, it identifies a set of limitations such as the low incidence of systematic reviews, which justifies conducting the SLM in the next stage of this study, and the limited international collaboration, indicating challenges for the theoretical consolidation and global articulation of knowledge in the field. Third, it identifies signs of conceptual reconfiguration with the recent rise of Agential Realism, Speculative Realism, and Postphenomenology, theories that expand the interpretive horizons in IS and point to a more critical and relational integration between humans, technologies, and sociotechnical practices. Each of these findings is discussed in detail below.

3.2.3.1 Overview of Research on Entanglement Theories in IS

To understand the development and consolidation of Entanglement Theories in IS, the evolution of the scientific output on the topic was examined over time (Table 5). The analysis focused on publication volume, document types, and patterns of collaboration among authors.

Table 5: General Overview of the Bibliometric Data

Description	Quantity
Main Information on the Data	
Period	January 1, 1992 to January 29, 2025
Sources	450 journals, books, and related outlets
Documents	A total of 669 documents were analyzed
Annual Growth	Annual growth rate of 5%
Average Age	Average age of documents: 10.8 years
Cit./Doc.	Mean of 17.23 citations per document
References	A total of 4,943 cited references
Authors	
Number of Authors	A total of 1,142 authors
Single-Authored Docs.	A total of 210 documents written by a single author
Co-Authors per Doc.	Mean of 2.26 co-authors per document
International Co-Auth. %	4.634% of documents involved international collaboration
Document Types	
Articles	304 articles published in scientific journals
Conference Papers	235 studies presented at conferences or workshops
Reviews	2 review papers
Others	128 editorial documents, notes, and special issue introductions

Source: Author's elaboration

The bibliometric analysis, based on 669 documents published between 1992 and January 2025, reveals an average annual growth rate of 5%, which indicates a continuous expansion of academic interest in the topic. Regarding scholarly collaboration, the data show that only 210 documents, approximately 31%, are single-authored, while the overall mean is 2.26 co-authors per document. International collaboration remains limited, since only 4.63% of the documents result from partnerships among authors from different countries. Concerning academic impact, the field exhibits an overall average of 17.23 citations per document. Although this is a reasonable indicator, it may be inflated by a small number of highly cited works. A total of 4,943 distinct references were cited, which suggests an extensive theoretical foundation.

A revealing aspect concerns the distribution of document types. Of the total analyzed, 304 documents, approximately 45%, are journal articles, followed by 235 conference papers, corresponding to 35%. Only two documents were classified as systematic reviews, which indicates a critical gap in the organization and assessment of the state of the art. This scarcity of review studies may hinder the consolidation of theoretical, conceptual, and methodological consensus. Additionally, the significant number of documents categorized as “Others,” consisting of 128 records that include editorial notes, introductions, and peripheral texts, may indicate a field that is still seeking legitimation and definition within the formal channels of science.

Overall, the current landscape portrays a promising and expanding field with increasing interdisciplinary interest. Nonetheless, it still faces important challenges, which include consolidating a more integrated theoretical identity, expanding international collaboration networks, and stabilizing its scientific output in a more continuous manner.

Despite the integrative potential of Entanglement Theories, combining them requires careful attention to the ontological tensions among approaches that adopt distinct views on entities, relations, and the constitution of reality. Such integration demands methodological caution and clarity regarding the ontological and epistemological premises of each theory in order to avoid collapsing fundamental differences into a generic notion of “entanglement.”

3.2.3.2 Key References and Their Articulation with Authors and Themes

This section analyzes how the most prominent external references cited in works related to Entanglement Theories in IS are connected to the most influential authors and to the recurrent themes identified through publication keywords. The aim is to understand how specific theoretical frameworks guide scientific production in the field and how these references are mobilized by different researchers and thematic domains.

Table 6 provides an overview of the most frequently cited references in the analyzed corpus, highlighting the works that constitute the theoretical foundation for research on Entanglement Theories in IS.

Table 6: Most Frequently Cited External References in the Analyzed Documents

Title	Author	Citations
Science in Action: How to Follow Scientists and Engineers Through Society	Bruno Latour	27
Sociological Review Monograph, P196	Michel Callon and John Law	21
Power, Action and Belief: A New Sociology of Knowledge?	Michel Callon and John Law	20
A Sociology of Monsters: Essays on Power, Technology, and Domination	John Law	20
Actor-Network Theory and IS Research: Current Status and Future Prospects	Geoff Walsham	17
Notes on the Theory of the Actor-Network: Ordering, Strategy, and Heterogeneity	John Law	16
Why Has Critique Run Out of Steam? From Matters of Fact to Matters of Concern	Bruno Latour	15
Making Things Public: Atmospheres of Democracy	Isabelle Stengers, Bruno Latour, and Peter Weibel	13
Reassembling the Social: An Introduction to Actor-Network-Theory	Bruno Latour	13
We Have Never Been Modern	Bruno Latour	12

Source: Author’s elaboration.

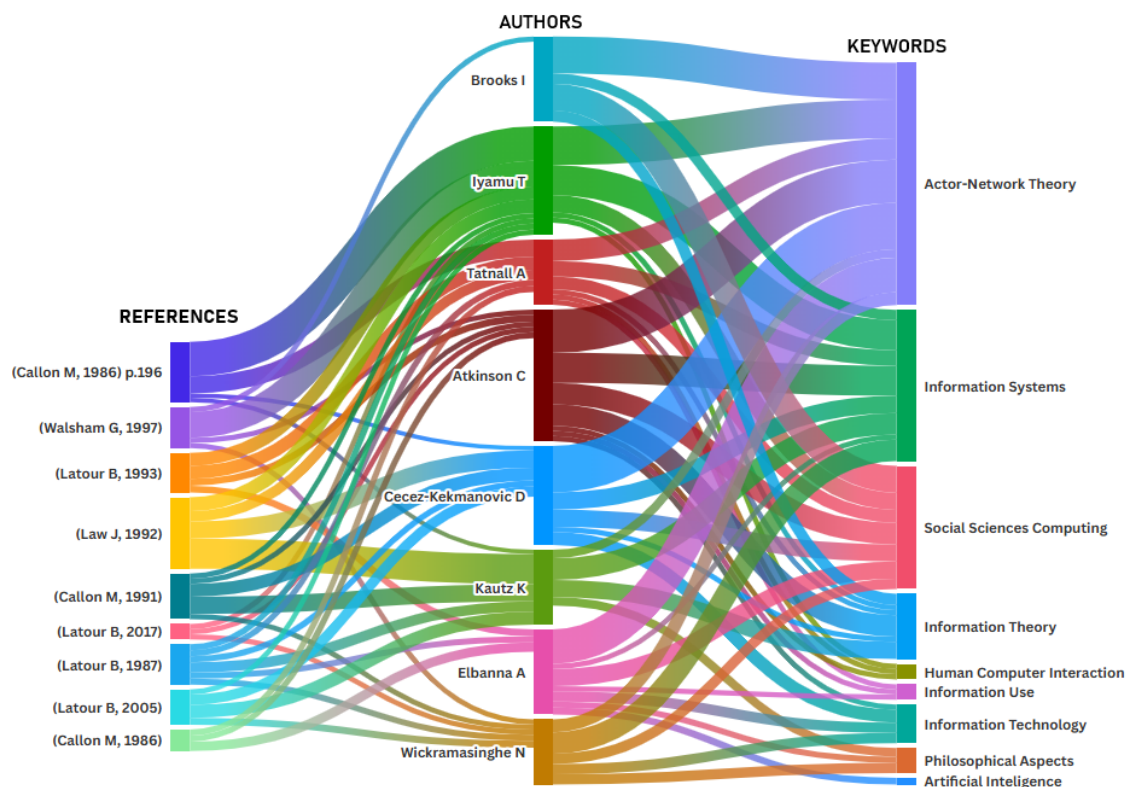
ANT stands out historically as the main theoretical and philosophical foundation in investigations related to Entanglement Theories in IS. Among the ten most frequently

cited titles, eight are authored or co-authored by Bruno Latour, Michel Callon, or John Law, who are the three central founders of ANT.

Although expressive, this result is also expected, given that ANT is the most established of the approaches analyzed. It reveals a clear preference for this theory within the scientific community and a form of paradigmatic stabilization in which ANT operates as an entry point for conceptualizing sociotechnical relations and the distributed agency of humans and nonhumans.

However, understanding the centrality of an approach requires more than recognizing its citation frequency. It also demands examining how it is mobilized in practice by researchers in the field. This involves going beyond citation counts to investigate how these references interact with the work of the most influential authors. In this context, Figure 9 maps the connections among leading authors, the references they most frequently cite, and the keywords associated with their publications. This visualization reveals how certain authors appropriate specific theoretical frameworks and articulate them with emerging themes, highlighting patterns of theoretical alignment and intellectual trajectories.

Figure 9: Most Frequently Cited References by Leading Authors and the Most Prevalent Keywords



Source: Author's elaboration using the Biblioshiny tool.

The diagram reveals a strong convergence among authors, references, and theoretical domains. Authors such as Atkinson C., Ceez-Kecmanovic D., Kautz K., and Elbanna A. maintain robust links to the works of Latour, Callon, and Law, indicating a solid theoretical affiliation with ANT. This adherence is also reflected in the keywords

associated with their publications, including “Actor-Network Theory,” “Information Systems,” and “Social Sciences Computing.”

While Cecez-Kecmanovic D. and Kautz K. associate the works of Latour and Callon predominantly with themes such as “Information Systems” and “Social Sciences Computing,” authors like Wickramasinghe N. and Elbanna A. broaden the thematic scope. They mobilize these same references to address topics such as information technologies, information use, philosophical perspectives, and even artificial intelligence. This expansion suggests that although a shared theoretical foundation exists, there are significant variations in how these theories are appropriated and articulated in relation to contemporary issues.

A particularly relevant case is the presence of **Walsham (1997)**, which appears among the most frequently cited references with 17 mentions. Walsham was one of the pioneers in articulating ANT with qualitative research in IS, emphasizing the analysis of interactions among technology, organizational context, and agency. His influence is evident among authors such as Iyamu T. and Brooks L., who appear to adopt this perspective to support investigations of a more interpretivist and sociotechnical nature.

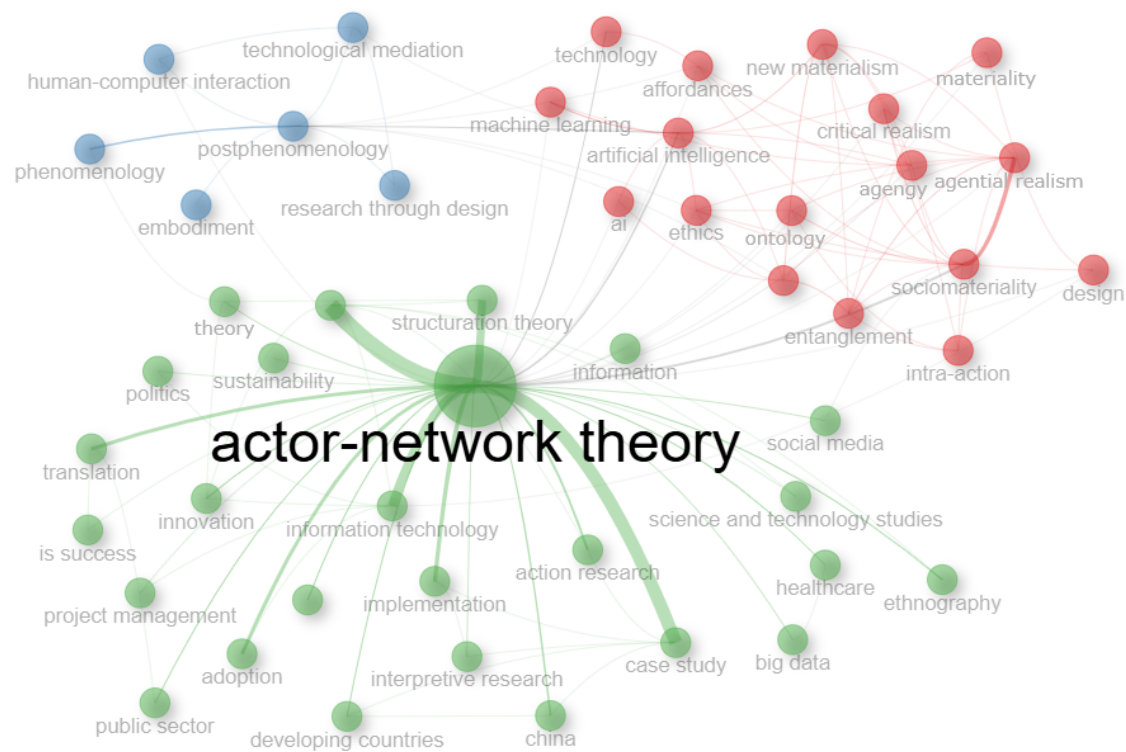
Finally, the keyword “Artificial Intelligence” appears only modestly in the analyzed corpus, yet it represents a conceptually promising presence. Although it is not among the main terms associated with ANT in the work of the more traditional authors, it emerges in connection with researchers who also draw on the references of Latour and Callon. This suggests an effort to bring discussions on distributed agency and materiality into dialogue with the ethical and epistemic challenges posed by artificial intelligence. This emerging connection indicates that Entanglement Theories are beginning to be mobilized to problematize AI beyond its treatment as a mere technical tool, opening space for broader reflections on agency, ethics, and materiality in contemporary computational contexts.

3.2.3.3 Thematic Evolution and Emerging Theoretical Approaches

The emergence of AI as a recent theme reinforces the need to identify other conceptual trends in ascension, shifts in research focus, and the appearance of new theoretical perspectives over time. To address this, the evolution of themes was examined through an analysis of the keywords used in the publications. This approach makes it possible to understand how the field has been restructured in response to theoretical advances, interdisciplinary influences, and new challenges, revealing both continuities and innovations within the research domain. Figure **10** presents a keyword co-occurrence analysis based on the 669 documents examined.

The term “Actor-Network Theory” occupies the center of the network and functions as a connector among multiple domains. The green cluster shows the connection between ANT and more established applications in IS and organizational studies. Keywords such as “information technology,” “project management,” “implementation,” “healthcare,” “developing countries,” and “case study” reveal the instrumental and applied use of the theory in institutional, methodological, and practical contexts. This core represents a pragmatic line of appropriation directed toward the analysis of sociotechnical systems in real-world environments.

Figure 10: Keyword Co-occurrence Network



Source: Author’s elaboration using the Biblioshiny tool.

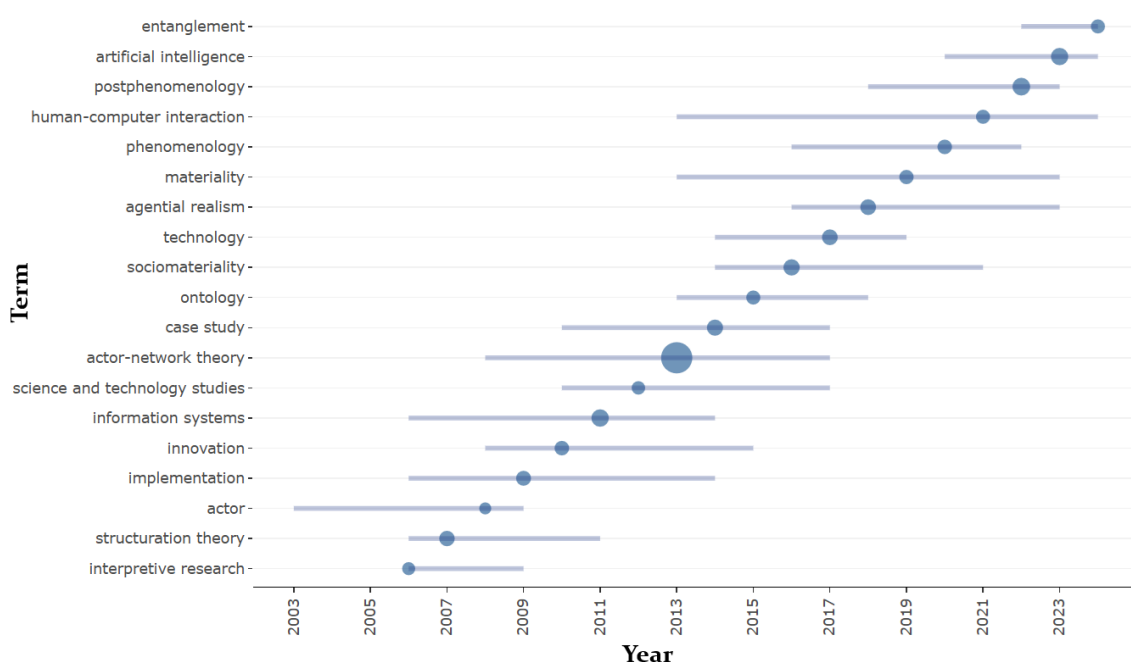
The blue cluster highlights a more conceptual axis oriented toward HCI, anchored in terms such as “postphenomenology,” “phenomenology,” “research through design,” and “technological mediation.” This network suggests connections between ANT and the phenomenological tradition, emphasizing interpretive methodologies and design-oriented critical approaches that are frequently associated with contemporary debates on ethics and technological practice.

The red cluster represents an ontologically and epistemologically dense strand structured around concepts associated with Agential Realism and Speculative Realism. Keywords such as “agential realism,” “intra-action,” “entanglement,” “materiality,” “agency,” “ontology,” and “sociomateriality” point to a deeper theoretical elaboration focused on the critique of the subject-object dualism and the reconfiguration of the notions of agency and reality. This group is also connected to contemporary topics such as “ethics” and “artificial intelligence,” indicating an effort to rethink the foundations of AI from perspectives that understand knowledge not as a representation of the world, but as something constructed within the interactions among people, technologies, and contexts.

Although the co-occurrence analysis helps identify central themes and how they relate to one another, it does not show how these themes evolve over time. To address this limitation, a temporal trend analysis was conducted, as presented in Figure 11.

In the early years of the historical series, terms such as “interpretive research,” “structuration theory,” “actor,” and “implementation” dominate the landscape, reflecting

Figure 11: Trending Topics



Source: Author's elaboration using the Biblioshiny tool.

an initial interest in methodological foundations, organizational practices, and technology adoption processes.

Starting in 2010, a conceptual shift becomes visible, marked by the consolidation of “actor-network theory” as the structuring axis of the field. Its peak between 2012 and 2014 coincides with the rise of themes such as “science and technology studies,” “case study,” “ontology,” and “materiality,” indicating the expansion of ANT as a framework for understanding distributed agency, relations between humans and nonhumans, and the role of materiality in the constitution of IS.

Between 2015 and 2018, another theoretical shift takes place with the emergence of terms more closely aligned with contemporary Entanglement Theories and posthumanist approaches. Concepts such as “sociomateriality,” “technology,” “agential realism,” and “materiality” gain prominence and remain influential in subsequent years. This movement reveals a transition from the traditional organizational focus toward a deeper problematization of relational ontologies and the material conditions of action.

The recent emergence of “entanglement” as a central term constitutes the most significant indication of an ongoing attempt to consolidate Entanglement Theories in contemporary research. It is a concept that accurately captures the growing sensitivity to the inseparability of humans, artifacts, and sociotechnical practices, while also functioning as an articulating axis for multiple theoretical, methodological, and epistemological approaches oriented toward non-anthropocentric perspectives.

The nearly simultaneous appearance of “artificial intelligence” suggests a promising trend that brings debates on AI into closer dialogue with the perspectives offered by Entanglement Theories. The recent presence of “human-computer interaction” also

draws attention, indicating a renewed convergence between these theories and critical studies in HCI.

This collective movement points to a field undergoing reconfiguration, in which new philosophical and ontological approaches begin to occupy a more prominent position, emerging as alternatives or complements to ANT. In this context, there is a visible effort to construct a more entangled perspective that integrates different theoretical approaches and enhances their sensitivity to the contemporary complexities of sociotechnical ecosystems.

3.3 Systematic Literature Mapping

The SLM sought to understand how Entanglement Theories have been mobilized by studies that employ Speculative Design. It aimed to identify trends and conceptual and methodological gaps, as well as to characterize the ways in which these theories are appropriated within the context of speculative practices.

3.3.1 Research Method

Six international databases were consulted: ACM Digital Library, IEEE Xplore, ISI Web of Science, ScienceDirect, Scopus, and SpringerLink. The search, conducted in January 2025, employed a combinatorial search string that intersected the axes of “entanglement theories,” “speculative design,” and “technology.” After applying inclusion and exclusion criteria, conducting full-text reading, and removing duplicates, 40 studies were selected. The process was carried out using the Parsif.al tool and validated by two reviewers, yielding a Cohen’s Kappa agreement index of 0.783.

3.3.2 Data Analysis

After the final selection of studies, the relevant data were extracted and analyzed. For each included article, information was collected regarding bibliographic data (year, authorship, country), the theories mobilized, the design practices described, the computational contexts of application, and the forms of conceptual appropriation.

The thematic categorization of the findings was guided both by these informational categories and by procedures inspired by Grounded Theory (Noble; Mitchell, 2016). Initially, one researcher conducted open coding of the studies, identifying recurring concepts (emerging themes) based on textual excerpts.

The resulting categories were refined through successive rounds of discussion among three researchers until a coherent set of patterns and conceptual gaps was consolidated.

3.3.3 Results and Discussion of the Systematic Literature Mapping

The analysis of the selected studies revealed different forms of articulation between Entanglement Theories and Speculative Design, highlighting both the potential for epistemological and critical advancement and the methodological and conceptual gaps

that remain. The main findings are presented below and organized into three parts: (i) the characterization of the specific contributions of each theory to Speculative Design, (ii) the identification of gaps and emerging trends, and (iii) the analysis of the benefits and challenges associated with incorporating these theories into Technological Design practices.

3.3.3.1 Synthesis of Related Work

Table 7 presents a synthesis of the ways in which different Entanglement Theories have been incorporated into Speculative Design within the context of Computing. The results show that each theory offers distinct contributions to the deepening and diversification of speculative practices in the field.

Table 7: Exploration of Entanglement Theories through Speculative Design

Relation	Exploration	Studies
Postphenomenology and Speculative Design	Material speculation and co-speculation aligned with postphenomenological commitments to investigate human relations	(Forlano; Halpern, 2023; Wakkary <i>et al.</i> , 2022)
	Articulation of more expansive and pluralistic notions of relations	(Wakkary <i>et al.</i> , 2022)
	Definition of agential and interactive affordances	(Kimura; Nakajima, 2023)
OOO and Speculative Design	Design fiction used to explore object-oriented perspectives for designing systems such as the Internet of Things	(Akmal; Coulton, 2020)
	OOO-informed metaprobes as an extension of design probes	(Encinas <i>et al.</i> , 2020; Kong <i>et al.</i> , 2021)
	Questioning the ontological understanding of fictional objects	(Encinas <i>et al.</i> , 2020; Coulton <i>et al.</i> , 2024)
ANT and Speculative Design	Considering computational artifacts and algorithms as actors	(Bekker <i>et al.</i> , 2023; Busboom, 2023; Encinas <i>et al.</i> , 2020)
	Research-through-Design (RtD) approaches combined with design futurization methods	(Busboom, 2023)
	ANT used as metaphor-oriented design	(Encinas <i>et al.</i> , 2020; Coulton <i>et al.</i> , 2024)
Agential Realism and Speculative Design	Challenging dualist views and emphasizing the heightened agency of nonhuman actors in intra-actions with humans	(Bekker <i>et al.</i> , 2023; Rozendaal <i>et al.</i> , 2024; Kong <i>et al.</i> , 2021; Lazar <i>et al.</i> , 2021)
	Speculative enactments used to investigate experiences and social concerns related to alternative realities with technologies	(Kong <i>et al.</i> , 2021; Rozendaal <i>et al.</i> , 2024; Wakkary <i>et al.</i> , 2022; Dörrenbächer <i>et al.</i> , 2023)
	Use of diffractive analysis	(Encinas <i>et al.</i> , 2020; Forlano; Halpern, 2023)
		(Wakkary <i>et al.</i> , 2022)

Source: Author's elaboration.

Postphenomenology contributes by emphasizing technological mediations in the relations between humans and artifacts and by supporting speculative practices centered on lived experience and on the relational capacities of technologies. In the dialogue between “Postphenomenology and Speculative Design,” the TTM (Verbeek, 2005b) stands out as it supports practices of co-speculation and *Worlding*¹ (Haraway, 2016), highlighting the possibilities for action that emerge from co-constitutive relations between humans and technologies (agential affordances) (Kimura; Nakajima, 2023).

The articulation between “OOO and Speculative Design” contributes by enabling the

¹ *Worlding* is a concept that understands the world not as a fixed or stable entity but as a verb - a continuous process of world-making.

exploration of hidden layers of technical systems through design fiction and speculative tools. Added to this is the use of metaprobes² (Encinas *et al.*, 2020), speculative probes informed by OOO that operate as devices for ontological investigation by exploring the existence and agency of objects beyond their instrumental functions (Encinas *et al.*, 2020; Coulton *et al.*, 2024). These practices aim to perform alternative ontologies and to instantiate new ways of existing in and with the world.

The presence of ANT in Speculative Design studies manifests at three levels: (i) the acknowledgment of the agency of computational artifacts (Bekker *et al.*, 2023), which legitimizes the agency of nonhumans by considering artifacts and algorithms as actors within sociotechnical networks; (ii) its mobilization as a complementary theoretical structure for understanding sociotechnical relations and guiding speculative methods (Busboom, 2023); and (iii) its metaphorical use as a narrative and critical framework (Encinas *et al.*, 2020; Coulton *et al.*, 2024). Although conceptually relevant, ANT has been only minimally employed in its descriptive methodological dimension. For example, there is a notable absence of instruments native to ANT, such as controversy mapping³ (Venturini; Munk, 2021), which could deepen the analysis of sociotechnical networks.

Agential Realism, in turn, has been mobilized in speculative enactments and diffractive analysis⁴ (Barad, 2007; Forlano; Halpern, 2023) as ways to investigate how intra-actions between humans and technologies perform alternative realities, amplifying distinct perspectives on sociotechnical phenomena. Although Agential Realism has emerged as a reference, its theoretical complexity means that concepts such as intra-action and diffractive analysis are still being mobilized in partial or implicit ways. Nonetheless, a movement toward conceptual maturation can be observed, pointing to the gradual incorporation of this approach in a more robust manner.

3.3.3.2 Gaps and Trends in the Articulation between Entanglement Theories and Speculative Design

Table 8 presents the main findings regarding the gaps and emerging trends in the articulation between Entanglement Theories and Speculative Design in the field of Computing.

Wakkary *et al.* (2022) identify epistemological and terminological difficulties in incorporating philosophical foundations that lie outside the traditional repertoire of Design and HCI, which remains shaped by functionalist logics and usability-centered approaches. The study by Benjamin *et al.* (2023) highlights a significant gap in the critical and comprehensive engagement with artificial intelligence technologies, particularly within design contexts. Although AI-based systems such as image-synthesis models are widely disseminated in everyday applications, their role in mediating human experiences of reality remains underexplored. Moreover, the authors observe that design research still treats AI predominantly as a tool or explanatory resource, neglecting its

²*Metaprobes* are objects for metaphysical inquiry, or artifacts developed to reveal tensions, values, and imaginaries surrounding the speculated technologies.

³Controversy mapping is an ANT method that charts disputes and negotiations around still-unstable issues, revealing how different actants construct meanings, alliances, and conflicts over time.

⁴From a sociomaterial perspective, diffractive analyses promote the understanding that ideas, practices, and facts are the effects of entanglements and webs of relations among human and nonhuman actors.

Table 8: Gaps and Trends in the Integration between Entanglement Theories and Speculative Design

Type	Description	Studies
Gaps	Dependence on traditional Design/HCI conceptual repertoires	(Wakkary <i>et al.</i> , 2022)
	Comprehensive Theoretical and Practical Engagement with AI	(Benjamin <i>et al.</i> , 2023)
Gaps	Integration of Ethics into Design Education	(Forlano; Halpern, 2023), (Homewood <i>et al.</i> , 2021)
	Design Methods for “More-than-Human Bodies”	(Homewood <i>et al.</i> , 2021)
Trends	Curricula Focused on Design Futures	(Forlano; Halpern, 2023)
	Growing Integration of Entanglement Theories	(Dörrenbächer <i>et al.</i> , 2023), (Bekker <i>et al.</i> , 2023), (Calderwood, 2024), (Encinas <i>et al.</i> , 2020)
Trends	Design as Theoretical Inquiry	(Forlano; Halpern, 2023)
	Focus on Ethics and Politics in Design	(Homewood <i>et al.</i> , 2021), (Henry, 2024)
Trends	Use of Design Fiction and Speculative RtD	(Benjamin <i>et al.</i> , 2023), (Dörrenbächer <i>et al.</i> , 2023), (Encinas <i>et al.</i> , 2020)
	Re-examination of Existing Models	(Henry, 2024)
Trends	Exploration of Co-creation with Nonhuman AI	(Tholander; Jonsson, 2023)
	Emphasis on Critical Educational Design	(Forlano; Halpern, 2023), (Bekker <i>et al.</i> , 2023)

Source: Author’s elaboration.

potential as speculative material and as an epistemologically active agent.

The study by (Homewood *et al.*, 2021) calls attention to gaps in design education with regard to the ethical formation of future professionals. Despite the increasing complexity of sociotechnical systems, educational practices continue to prioritize technical and anthropocentric competencies while overlooking approaches that foster critical thinking, ecological sensitivity, and social responsibility. (Forlano e Halpern, 2023) expand this critique by arguing that the most widespread branch of Speculative Design tends to generate hypothetical artifacts detached from concrete sociopolitical realities, neglecting the role of design as a situated and ethically responsible practice. The absence of literacies for ethical futures underscores the urgency of reconfiguring curricula in Computing, particularly in HCI, to include speculative, participatory, and post-human practices.

In contrast, several emerging trends seek to address these challenges. One of them is the growing integration of Entanglement Theories into HCI and Speculative Design through the adoption of posthumanist, multispecies, and performative approaches ((Dörrenbächer *et al.*, 2023; Calderwood, 2024; Bekker *et al.*, 2023)). This direction materializes in practices such as “performative protocols,” which embrace indeterminacy and recognize distributed agency as the ethical foundation for designing with AI (Calderwood, 2024). The use of design fiction and speculative RtD approaches is also becoming consolidated as a means to problematize complex sociotechnical ecosystems, although authors such as (Henry, 2024) warn of their potential critical dilution when adopted in an instrumental manner. In response to this issue, there is a movement to reinterpret these models through post-anthropocentric perspectives.

In addition, there is an increasing push for a critical educational reorientation that values curricula more attentive to speculation, situated ethics, and the ontological complexity of sociotechnical systems ((Forlano; Halpern, 2023; Bekker *et al.*, 2023)). Finally, GenAI emerges as a transformative vector, acting both as a tool and as a co-authoring agent in the creative process, prompting a reconfiguration of the role of

nonhumans in design (Tholander; Jonsson, 2023).

3.3.4 Conclusion of the Systematic Literature Mapping

The combination of Entanglement Theories and Speculative Design in technological domains, especially in HCI, presents a distinct set of challenges, which are summarized in Table 9.

Table 9: Challenges in Integrating Entanglement Theories and Speculative Design

Challenge	Study
Complexity and Abstraction	(Bekker <i>et al.</i> , 2023)
Difficulty in Implementation and Evaluation	(Kimura; Nakajima, 2022), (Forlano; Halpern, 2023)
Issues of Representation and Agency	(Bekker <i>et al.</i> , 2023)
Definition of Responsibility	(Ståhl <i>et al.</i> , 2022), (Bekker <i>et al.</i> , 2023), (Homewood <i>et al.</i> , 2021)
Need for New Skills and Education	(Forlano; Halpern, 2023), (Homewood <i>et al.</i> , 2021)
Risk of Marginalization	(Forlano; Halpern, 2023), (Henry, 2024)
Managing Power Imbalances	(Benjamin <i>et al.</i> , 2023)

Source: Author's elaboration.

One of the main challenges lies in the complexity and abstraction of these theories, which makes their operationalization difficult in educational or practical contexts (Bekker *et al.*, 2023). Another challenge concerns how to represent the agency of more-than-human entities, such as algorithms, bacteria, forests, or sensors, without resorting to anthropocentric metaphors that project human qualities onto these agents or to practices that render them invisible in the design process (Bekker *et al.*, 2023).

It is precisely at this point that the ethical challenge of “defining responsibility” emerges (Ståhl *et al.*, 2022; Bekker *et al.*, 2023; Homewood *et al.*, 2021). When imagining speculative futures, who is responsible for the visions being projected? Who is included or excluded from these futures? Ståhl *et al.* (2022) draw attention to the risk that co-speculation may overlook the real impacts that certain worldviews can reinforce. With respect to the risk of marginalization, Forlano e Halpern (2023) emphasize that certain design practices, even when motivated by good intentions, may end up silencing voices and experiences that fall outside dominant normative patterns, such as those of people with disabilities, racialized populations, or historically excluded groups.

This problem becomes even more pronounced in the context of algorithmic technologies, which operate under claims of neutrality, yet may intensify inequalities and power asymmetries (Benjamin *et al.*, 2023). This requires design to reconsider its role as a mediator of multiple and asymmetric worlds, attending more carefully to nonhuman forms of agency.

In light of these challenges, Forlano e Halpern (2023), Homewood *et al.* (2021) argue for the reformulation of design curricula and pedagogical practices, with an emphasis on developing critical, speculative, and relational skills. However, this movement faces a significant obstacle: the difficulty of translating Entanglement Theories into educational practices without reducing their ontological complexity or instrumentalizing them in superficial ways (Bekker *et al.*, 2023).

Addressing these challenges opens space for a series of benefits, which are presented

in Table 10.

Table 10: Benefits of Integrating Entanglement Theories and Speculative Design

Benefit	Justification
Theoretical Depth	Provides a robust ontological and epistemological foundation for understanding relations among humans, technologies, and the world as dynamic and non-binary intra-actions.
Expansion of the Design Scope	Expands the focus of design to include entire sociotechnical systems and nonhuman agents, opening new fields of speculation.
Enhanced Criticality and Reflection	Enables the exposure of values, assumptions, and often-invisible sociotechnical impacts, deepening the critical dimension of design.
Generation of Ethical and Political Insights	Helps formulate new ethical questions and political approaches by revealing distributed agency and interdependent relations.
Potential for Interdisciplinary Collaboration	Facilitates dialogue across areas such as philosophy, art, science, and technology, enriching design practices and perspectives.
Reframing Notions of Success and Failure	Reframes the understanding of failures as effects of complex sociomaterial tensions rather than as absences to be corrected.

Source: Author's elaboration.

First, there is a deepening of theoretical foundations, since design can rely on epistemologies that recognize the intra-action among humans, technologies, and environments. In this sense, the methodologies, tools, and design frameworks, as well as the intentions of facilitators and the dynamics enacted in speculative activities, actively participate in constituting meanings, shaping the projected sociotechnical ecosystems, and influencing the agencies involved. This recognition makes Speculative Design more attentive to the material-discursive conditions that shape processes of imagination, reflection, and creation.

Second, the scope of design expands to consider not only human users but also nonhuman agents, systems, and infrastructures (Forlano; Halpern, 2023; Bekker *et al.*, 2023). This broadened visibility of other agents refines the critical and reflective capacity of design by exposing implicit values, naturalized assumptions, and forms of silencing embedded in technological practices (Bekker *et al.*, 2023; Forlano; Halpern, 2023; Wakkary *et al.*, 2022). It also reveals the normative layers that shape artifacts and computational systems by uncovering how certain worldviews are privileged while others are excluded. As a result, new ethical and political insights emerge (Homewood *et al.*, 2021; Henry, 2024), which are essential for imagining more just futures that are responsive to diverse experiences and forms of existence, particularly in contexts involving more-than-human agencies.

Moreover, this approach supports interdisciplinary collaboration by fostering productive dialogues among computing, philosophy, the arts, and the humanities (Calderwood, 2024; Dörrenbächer *et al.*, 2023). It expands the heuristic potential of design and encourages the creation of hybrid methodologies capable of engaging with the sociotechnical complexity of contemporary ecosystems.

Finally, the articulation between Entanglement Theories and Speculative Design reframes the understanding of success and failure. Instead of seeking to correct errors according to traditional metrics, design begins to value the insights that emerge from sociomaterial tensions, ambiguity, and indeterminacy, which are constitutive elements of the realities in which it intervenes (Kimura; Nakajima, 2022; Forlano; Halpern, 2023).

3.4 Final Considerations of the Chapter

This chapter presented a literature review aimed at consolidating a robust theoretical and methodological foundation on Entanglement Theories and their articulation with Speculative Design in the field of Computing. The combination of the Bibliometric Analysis and the SLM proved to be strategic for understanding both the historical trajectory and the current state of academic discussions, bringing together broad quantitative data with a critical and in-depth qualitative interpretation.

The Bibliometric Analysis enabled the identification of key authors, collaboration networks, most cited works, and thematic trends that have shaped the development of Entanglement Theories in Information Systems over the past three decades. This overview revealed the centrality of ANT as a foundational reference, while also highlighting the recent emergence of approaches such as Agential Realism, Speculative Realism, and Postphenomenology, indicating a movement of theoretical reconfiguration in the field. Despite these advances, significant limitations were observed, including the low rate of international collaboration and the scarcity of integrative reviews. These gaps reinforce the need for more systematic and theoretically grounded investigations.

Complementing this, the SLM deepened the analysis by examining how these theories have been appropriated in studies that employ Speculative Design within computational contexts. The qualitative analysis of the 40 selected studies revealed both the potential for epistemological expansion and the methodological limitations in applying these approaches. Distinct forms of contribution from Entanglement Theories to speculative practices were identified, along with emerging trends such as the emphasis on ethical critique, co-speculation with nonhuman agents, and curricular reform aimed at addressing the complexities of contemporary sociotechnical systems.

The integration of bibliometric and systematic methods provides a more comprehensive view of the literature. Together, these approaches offer a mapping of the foundational milestones of Entanglement Theories, revealing how these foundations have been reinterpreted and applied in contemporary studies that investigate possible futures through Speculative Design. This body of related work therefore forms a continuous spectrum between foundational and recent contributions, supplying essential inputs for the formulation of the framework proposed in this dissertation.

4. The Proposal of the Sociotechnical Entanglement Framework for a Post-Anthropocentric Design

This chapter presents the central contribution of this dissertation: the *Sociotechnical Entanglement Framework* (SEF), a conceptual and methodological structure that integrates Entanglement Theories with Speculative Design to guide post-anthropocentric technological design practices.

The chapter begins with a comparative analysis of Entanglement Theories, highlighting their points of convergence and conceptual tensions, such as the centrality of relations, the rejection of anthropocentrism, and the emphasis on materialities. It then redefines sociotechnical networks in light of this theoretical constellation, expanding the traditional understanding of relations among humans, technologies, and institutions. From this dialogue, six post-anthropocentric principles are formulated to guide the SEF's practice, operating as ethical, ontological, and methodological directives.

Finally, the chapter presents the conception and refinement process of the framework, detailing its architecture, its internal structure, and its role as a mediating apparatus between theory and practice. This movement consolidates the conceptual foundation that will support, in the following chapter, the presentation of the tools developed to operationalize the SEF in workshops and speculative design processes.

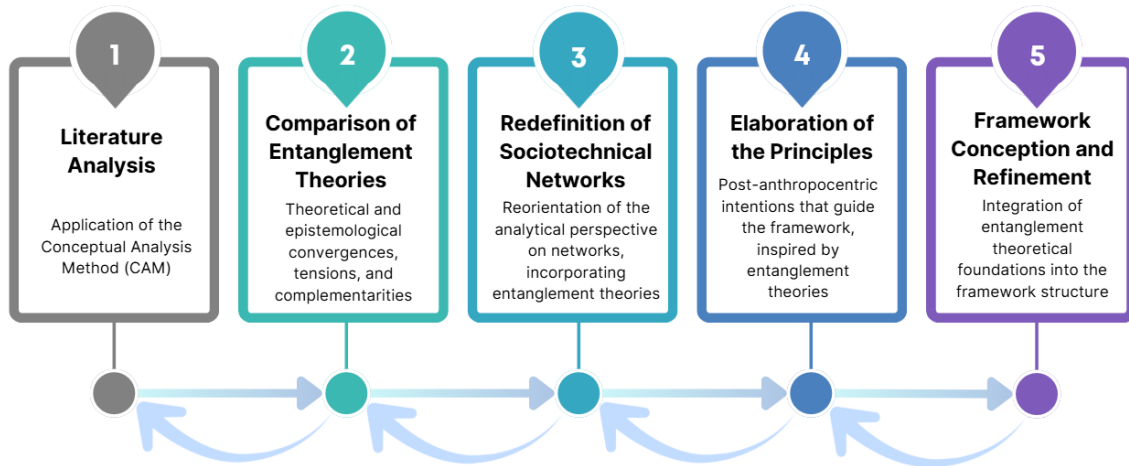
4.1 Contextualization

As discussed in previous chapters, Entanglement Theories provide a robust theoretical foundation for sustaining a post-anthropocentric perspective in the technological design process, while Speculative Design offers a privileged terrain for incorporating such a perspective.

This chapter presents the integration of Entanglement Theories into Speculative Design, resulting in the SEF, a framework that articulates post-anthropocentric principles derived from the entanglement literature and proposes a methodological pathway to guide ethical, reflexive, and sociotechnically sensitive design practices. The development of the SEF followed five main stages, illustrated in Figure [12](#).

In **Stage 1**, a comprehensive literature analysis was conducted, encompassing both the theoretical foundations and the results of the bibliometric and systematic analyses. This theoretical basis supported **Stage 2**, which focused on comparing Entanglement Theories and identifying their epistemological convergences, tensions, and complementarities. Building on this understanding, **Stage 3** involved redefining sociotechnical networks through the lens of Entanglement Theories, enabling a reorientation of the analytical perspective on human and non-human relations. In **Stage 4**, the post-anthropocentric principles that guide the framework were formulated, culminating in **Stage 5** with the conception and refinement of the framework, which integrates the theoretical foundations of entanglement and Speculative Design.

Figure 12: Stages for constructing the SEF framework



Source: Author's elaboration.

4.2 Comparative Analysis of Entanglement Theories

Integrating Entanglement Theories with Speculative Design involves significant challenges, given that each approach is grounded in its own ontological and epistemological assumptions. Nonetheless, they share important commonalities, such as the rejection of both social and technological determinism and a strong emphasis on relations. Table [11](#), developed on the basis of Chapters [2](#) and [3](#), presents a synthesis of these approaches, highlighting their conceptual convergences, tensions, and distinctions.

This comparison provides a conceptual foundation for the development of the framework proposed in this dissertation. By identifying convergences and tensions among the theories analyzed, it becomes possible to align their contributions with different phases of the speculative process, such as describing the current ecosystem, imagining futures, designing technological interventions, and assessing their consequences. In this way, the comparative matrix organizes the theoretical landscape and enables the construction of a post-anthropocentric approach oriented toward Speculative Design.

4.3 Redefining Sociotechnical Networks from an Entanglement Perspective

The analysis of the theoretical approaches that ground this study enabled a shift in perspective on sociotechnical networks, replacing the traditional view with a non-anthropocentric understanding aligned with Entanglement Theories. Figure [13](#) illustrates this approach, which understands networks as entanglements shaped by mediations and reciprocal transformations among the observer, artifacts, society, and the environment.

By introducing the concept of the actant, ANT expands the notion of agency by including non-human entities, recognizing that they are also capable of exerting

Table 11: Comparison of Common Elements Across Entanglement Theories.

Aspect	ANT	Postphenomenology	Speculative Realism	Agential Realism
Agency	“Generalized symmetry”: agency is distributed equally among actants (human and non-human actors).	“Technology is not neutral”: it shapes behaviors and, when incorporated into everyday life, becomes a practical extension of human agency.	“Autonomy of objects”: an object is never fully exhausted in its interaction with another; it may or may not reveal its properties.	“Agency is relational,” non-intentional, distributed, and performative; it emerges through intra-actions between humans and non-humans.
Relations and Interactions	Relations are dynamic and central to the existence and definition of actants.	Relations between humans, technologies, and the world are mediated by technology.	Relations are decentralized, although objects maintain ontological autonomy.	Relations emerge through discursive-material practices (intra-actions).
Ontology	Actors do not possess a fixed essence; their existence is defined by their performance within the network.	Humans and technologies do not exist independently; they are co-constituted.	Advocates a “flat ontology,” in which all objects hold equivalent ontological status.	Boundaries between humans and non-humans dissolve through intra-actions.
Epistemology	Constructed through the analysis of associations and networks. To know is to trace relations and their effects.	Instruments and technologies shape perception, experience, and what is understood as reality and truth.	The reality of objects is only partially accessible, but it is possible to speculate beyond human perception, breaking with correlationism.	Knowledge is produced in intra-actions, without separating observer and observed; it is shaped by material practices and discursive contexts.
Methodological Approach	Descriptive: traces associations and maps heterogeneous networks of humans and non-humans to understand how connections generate meaning.	Phenomenological and Interpretive: analyzes how technologies mediate human experience and transform relations with the world.	Speculative: explores alternative realities and possibilities, investigating the existence and capacities of objects beyond human access.	Diffraction: whereas reflection presupposes a separation between observer and observed, diffraction focuses on the interferences and effects that emerge from intra-actions.

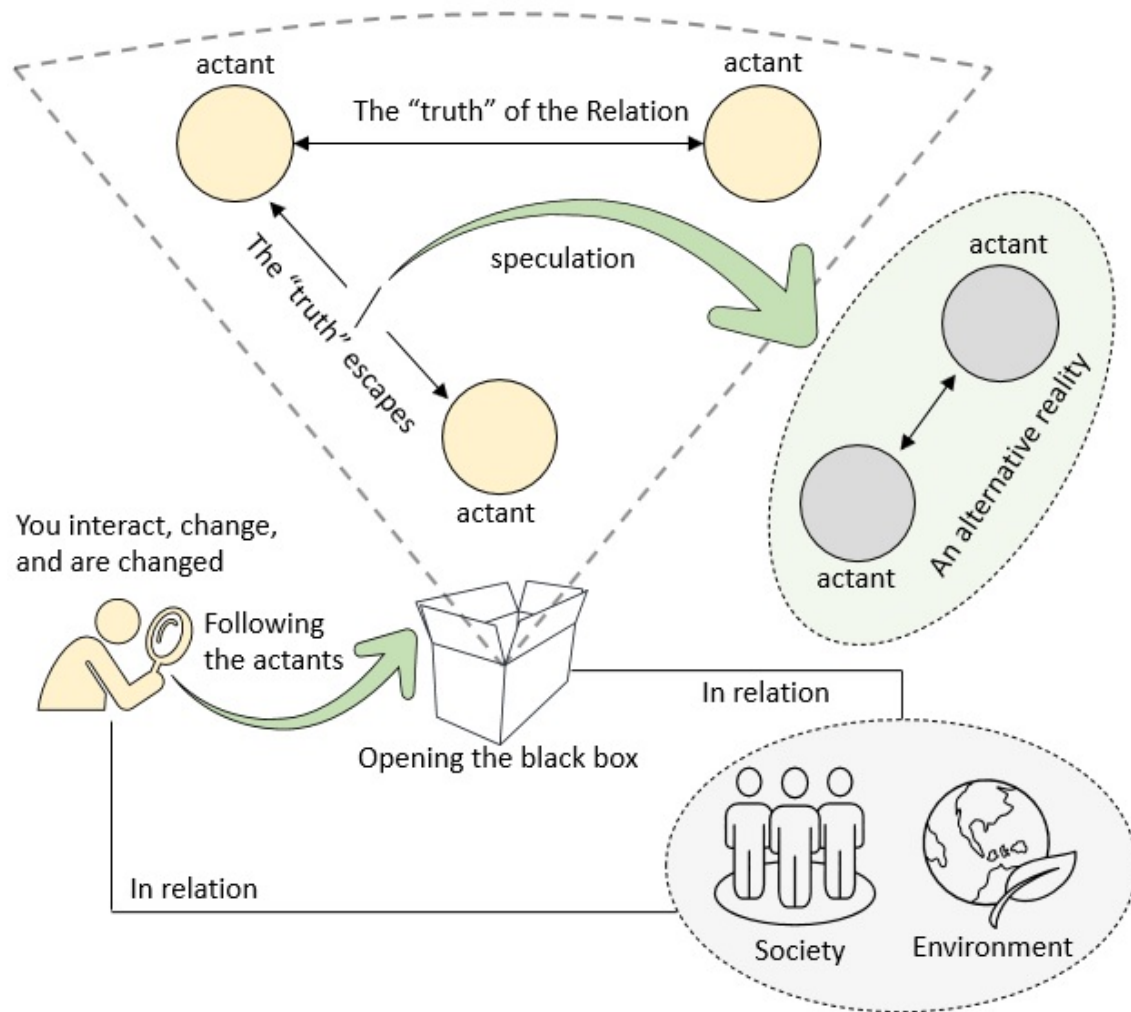
Source: Author’s elaboration.

influence within a sociotechnical network and acting as potential stakeholders.

According to [Latour \(2005a\)](#), ANT invites us to follow the actants, tracing their paths and interactions in order to understand the roles they play and the relations they establish with other elements of the sociotechnical network. In this process, what Latour calls black boxes may emerge. A social system or a technology, for instance, once incorporated into everyday life, tends to be perceived solely in terms of its functionality, without questioning its internal workings. The risk of this naturalization lies in the fact that, by taking something for granted, one fails to notice the connections, controversies, and negotiations that made its existence possible. For this reason, Latour recommends a continuous effort to open black boxes and reveal the networks and mediations that sustain them.

However, according to Speculative Realism, particularly within Object-Oriented Ontology (OOO), even when one seeks to map the role of actants, describe their relations, or open a black box, access to reality remains partial. Reality itself cannot be fully accessed, because every act of description or observation captures only a limited portion of its possible manifestations. There are also situations in which opening black boxes is impossible, which makes reality even more opaque. One example involves companies that restrict access to information about the internal functioning of their systems for intellectual property reasons, preventing a complete understanding of their

Figure 13: Understanding sociotechnical networks through the lens of Entanglement Theories.



Source: Author's elaboration.

technological and sociotechnical dynamics.

In such cases, the gap left by the inaccessibility of reality is addressed through speculation, which enables the construction of alternative realities. This process is not foreign to scientific or everyday practice, since even when one has access to what is considered objective reality, there is always a layer of subjectivation involved in its interpretation. The difference is that, by adopting this perspective, it becomes explicit that every understanding of sociotechnical networks is permeated by mediations, interpretations, and imaginings that also participate in the constitution of reality. The speculative plane constructs critical hypotheses that denaturalize stabilized discourses, especially in contexts shaped by strategic interests and deliberate opacity, such as social media platforms and GenAI systems.

Moreover, in contrast to simplistic “double-click” explanations, which reduce the relation between cause and effect to a direct and predictable sequence, speculation makes it possible to problematize these interpretations by introducing the emergent and

unforeseen effects that arise from sociotechnical scenarios themselves. For example, when analyzing the use of recommendation algorithms in streaming platforms, a “double-click” explanation would limit the understanding to the relationship between a user’s choice and the system’s automatic suggestion. A speculative perspective, however, makes it possible to consider how such algorithms reconfigure cultural behaviors, reinforce consumption patterns, and even shape collective identities, revealing a network of effects that is far more complex and interdependent.

Given the infinity of actants and the multiple projected possibilities, the speculative plane does not aim to exhaust reality in its parts or effects. It begins from the recognition that, even with the mapping of relations and the incorporation of speculative processes, uncertainty remains a constitutive feature of sociotechnical networks.

The observer, when describing the weaving of this network and activating their own layer of subjectivation, becomes fully implicated in the co-constitution of sociotechnical reality. The observer does not merely interact with the world but intra-acts with it (Barad, 2007). This means that perception is not external or subsequent to the phenomenon but a constitutive part of it. Sociotechnical reality and the observer’s perception co-emerge within the same process of materialization and meaning.

Postphenomenology contributes to the understanding that, while the observer participates in the co-constitution of the world, the technological apparatus that enables this observation also transforms the observer’s relation with the world. In every technological interaction, there is a double movement of transformation. When interacting, the subject modifies the world and is, at the same time, modified by it.

4.4 Formulation of the Post-Anthropocentric Principles

By reorienting the analysis of sociotechnical networks through the lens of Entanglement Theories, it became possible to formulate six post-anthropocentric principles that guide the understanding of these networks. These principles synthesize fundamental characteristics and were articulated to constitute a proposal for Speculative Design grounded in Entanglement Theories. They express the epistemic, ontological, and axiological intentions that informed the development of the Sociotechnical Entanglement Framework (SEF), the tools that compose it, and the projects resulting from its application. The principles that support this approach are presented below.

4.4.1 Non-Human Actors Must Be Made Visible

The understanding of sociotechnical ecosystems has long been guided by an anthropocentric view that separates subject and object, mind and matter. Both technocentrism and anthropocentrism share this fragmentation, inherited from the philosophical disputes of the seventeenth century, when Cartesian dualism prevailed over Leibniz’s monism (Latour, 2012). Descartes separated mind and matter by attributing to humans the exclusive possession of reason and agency, while treating matter as passive and subject to manipulation. Leibniz, in contrast, proposed an indivisible and interconnected reality (Cassells, 2019), yet this view lost ground with the consolidation

of dualism, which profoundly shaped modernity and classical materialism.

Entanglement Theories emerge as a critical response to this dominant paradigm by advocating a reconfiguration of the relations between humans and non-humans. They challenge the conception of nature as passive by asserting that reality is co-constituted through dynamic interactions among material and cultural elements (Latour, 2012; Kruger, 2021). This perspective makes visible the active participation of non-human actors in sociotechnical processes.

These theories also broaden the understanding of agency by recognizing that action is not restricted to humans. ANT maintains that any entity capable of influencing the course of an action should be treated as an actant, whether a person, a machine, a text, or a piece of code (Latour, 1987). Agential Realism proposes that agency is not a pre-existing property of entities but a force that emerges from intra-actions, from encounters in which humans and non-humans are mutually constituted (Barad, 2007). Postphenomenology argues that technologies do not merely mediate experience but also transform the relation between humans and the world, shaping perceptions, choices, and behaviors (Verbeek, 2005b). OOO holds that every object possesses its own reality, which reveals itself only partially through relations, and that this capacity to disclose or withhold aspects of itself constitutes a form of agency (Harman, 2011).

4.4.2 Human Agency Is Not Autonomous but Mediated

The notion that human agency is autonomous and voluntary is grounded in the assumption that human actions derive from internal intentions that operate independently of external mediations. This idea, however, has been widely contested by theoretical currents that recognize the active participation of non-human elements in the constitution of action. Among these currents, Postphenomenology stands out by examining how technical artifacts profoundly influence perception, experience, and even the formation of the subject (Ihde, 1990).

From a postphenomenological perspective, human agency results from relations mediated by technologies, in which subjectivity does not precede these mediations but is constituted within and through them. Technological artifacts modulate everyday experience by determining what becomes perceptible, understandable, or actionable, often in subtle and invisible ways (Oogjes; Wakkary, 2017). Human agency, therefore, emerges from the material and symbolic ties with the technologies that inhabit and structure our world (Hauser *et al.*, 2018).

Recognizing that human agency is not autonomous means understanding it as co-produced by the technologies that compose sociotechnical networks. Technologies shape human intentions by participating actively in processes of interpretation, decision-making, and action (Verbeek, 2005a; Ihde, 1990). Thus, human will emerges from a mediated field in which actants operate together. In this sense, human action is always entangled with technical action.

This understanding gains renewed relevance in the context of GenAI. These systems do not merely execute pre-programmed tasks but also participate in creative and exploratory processes. Krakowski (2025) highlights how GenAI transforms the notion of

agency within organizations by enabling hybrid configurations in which humans and machines collaborate in defining problems and seeking solutions. Instead of functioning solely as tools, these systems operate as complementary cognitive artifacts that actively shape human cognition, learning, and creativity. From this perspective, agency becomes distributed among human and artificial actors in dynamic and iterative relations, reinforcing the idea that subjectivity and intentionality are emergent properties of entangled sociotechnical networks.

4.4.3 Reality Is Relational and Irreducible to Totality

Understanding reality from a relational perspective implies recognizing it as a dense and dynamic fabric of interactions among humans and non-humans (Latour, 1987; Latour, 2005a). This requires overcoming reductionist explanatory models and reopening the black boxes that stabilize systems and naturalize power relations. These black boxes must be dismantled in order to reveal the processes through which sociotechnical groups are constructed, maintained, and transformed (Latour, 1987).

However, caution is needed when adopting the network of relations as the sole interpretive lens for sociotechnical reality. Although this approach makes it possible to trace the connections among actants, it remains largely anchored in what is visible, observable, and mappable, that is, what can be followed and described. There is a risk that distributed agency within the network may be interpreted merely as technical functionality, which would diminish its critical and political potential.

Cheon (2023) demonstrates this risk through an analysis of patents in logistics centers, in which the network formed by humans and artifacts does not reflect mutual recognition or relational symmetry, but instead reveals a project of functional subordination. The human body, captured by the logic of automation, becomes an invisible infrastructure that is tolerated only insofar as it is useful, replaceable, and subject to surveillance. In such cases, distributed agency does not promote emancipation or balance; it becomes an instrument of capture and control.

In this context, it becomes evident that network analysis must be complemented by an ethical and ontological stance that questions how connections are established and whom they serve, who is made visible and who is silenced within this web of entangled relations. Even the most sophisticated relational approaches do not exhaust the complexity of the real. There is always a dimension of reality that escapes perception, remaining withdrawn, opaque, and resistant to definitive description or explanation. Recognizing this is essential to avoid confusing traceability with completeness or agency with equity. Reality is relational, yet it is not fully accessible, transparent, or completely comprehensible.

4.4.4 We Must Speculate in the Face of Uncertainty

Speculative Realism does not treat zones of uncertainty as failures to be corrected but as opportunities for speculative inquiry. Given the impossibility of directly grasping reality, it becomes necessary to adopt modes of thought that welcome what escapes perception. Meillassoux (2006) critiques correlational thinking, which limits knowledge

to the relation between thought and being. In this view, everything that becomes accessible is already conditioned by human cognition. To break with this restriction, he proposes the notion of an absolute real, that is, a reality that exists independently of consciousness. This real does not depend on human mediation to exist, and its existence demands modes of thought capable of accommodating what exceeds representation.

OOO holds that every entity possesses an irreducible core that never fully reveals itself (Harman, 2011). This partial withdrawal requires a speculative attitude toward the world. Understanding becomes an exercise in constructing meaning at the edges of perception. Knowledge does not arise from the total apprehension of an object but from the speculative exploration of the gaps between what is revealed and what remains concealed.

The Entoptic Field Camera developed by Benjamin *et al.* (2023) materializes this principle by destabilizing the relation between perception and image. The device replaces the direct representation of the world with a sensory translation mediated by AI. In this process, the image ceases to function as a mirror and becomes a speculative field. To inhabit uncertainty in this context does not mean renouncing knowledge but recognizing that the indeterminate is a constitutive element of experience and meaning-making.

4.4.5 In Defense of a Cosmopolitics of Hybrids

To proactively defend a cosmopolitics of hybrids means breaking with the modern legacy grounded in the logic of purification, an operation that artificially separates science and politics, nature and culture, human and non-human (Stengers, 2010). This separation, however, never materialized in practice (Whitehead; Douchement, 1920). What emerged instead was an incessant proliferation of hybrids (Latour, 2012), sociotechnical entities composed of inseparable entanglements of facts, values, technologies, and affects. In this sense, cosmopolitics is not a conciliatory utopia but a practice of recognition and accountability for the multiple agencies that co-produce reality.

The figure of the cyborg, proposed by Haraway (2013a), exemplifies this vision by suggesting a relational and embodied stance that traverses modern dualisms. The cyborg is not an anomaly but the very mode of being in the contemporary world, in which humans, machines, and species are co-constituted within networks of interdependence. This perspective implies a fundamental shift in how design is approached: we do not design merely to meet the needs of individual users but in response to a world of which we are a part and which is also part of us.

Approaches such as “more-than-human data interaction” (Stead *et al.*, 2022) and “designing for the pluriverse” (Coulton *et al.*, 2024) offer concrete pathways for incorporating the cosmopolitics of hybrids into the design of sociotechnical networks. Rather than reinforcing extractivist and anthropocentric logics, as critiqued by Dunbar e Speed (2024), these approaches advocate the imagination and construction of infrastructures that are sensitive to data ecologies, diverse cosmologies, and interspecies alliances.

4.4.6 Ethics and Responsibility Emerge within Sociotechnical Relations

Postphenomenology and Agential Realism reconceptualize ethics not as a purely normative domain but as something that emerges from sociotechnical relations themselves. Verbeek (2015) argues that designing technologies also means designing ways of being in the world, which implies an inescapable ethical responsibility in the creation of technical artifacts. This responsibility goes beyond future consequences; it also involves shaping the very conditions of possibility for action and experience in the present.

Complementarily, Barad (2007) proposes that reality, meaning, and ethics are not pre-given entities that precede relation. Instead, they are continuously negotiated through discursive-material practices by which the world takes form, becomes intelligible, and becomes inhabitable. Ethics, therefore, is not an external judgment but a mode of accountability for the configurations that materialize within these sociotechnical networks. In this context, the speculative enactment of sociotechnical networks becomes a relevant strategy for revealing how agency and responsibility are configured in the relations among actants.

Akmal e Sandoval (2022) proposes a post-anthropocentric design approach for Human-Agent Interaction (HAI) grounded in OOO, in which artificial agents are treated as autonomous entities. The concept of “trans-objects” is introduced to indicate their potential to perform socially significant roles. Using the RtD approach, the study explores new interaction models.

Similarly, Rozendaal *et al.* (2024) adopts a performative approach to Human-Robot Interaction (HRI), combining virtual reality and theatre to demonstrate how agency and meaning emerge situationally rather than from fixed scripts. A virtual robot manipulated by a puppeteer under algorithmic constraints requires participants to interpret its behavior contextually, revealing the co-production of meaning in the relations among humans, technology, and the environment.

In the field of AI, recent studies have emphasized that AI should not be conceived as a fixed or autonomous entity but as a phenomenon in continuous formation, with multiple versions situated within the sociotechnical practices through which it is produced. Scott e Orlikowski (2025) propose the concept of AI-in-the-making precisely to highlight this contingent and relational nature of AI, within a sociomaterial genealogy that aligns directly with the principles of Agential Realism and the intra-active performativity discussed earlier.

4.5 Conception and Refinement of the Sociotechnical Entanglement Framework

For the conception and refinement stage of the SEF, a heuristic design procedure was adopted (Nielsen; Molich, 1990), understood as an iterative process of evaluation and improvement guided by theoretical and methodological criteria. Rather than relying at this stage on empirical tests or external validations, the preliminary structure of the SEF was analyzed using heuristics derived from the Entanglement Theories themselves, such as symmetry between humans and non-humans, distributed agency, constitutive

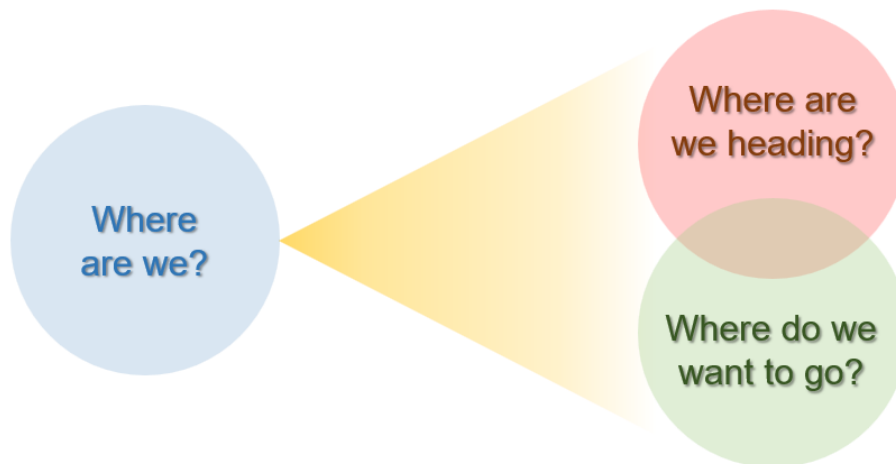
relationality, and the performativity of sociotechnical networks.

These heuristics functioned as criteria of internal coherence, allowing for the identification of conceptual gaps, epistemological misalignments, and excessive human centrality in the initial formulation of the model.

Based on these analyses, successive cycles of revision were conducted, resulting in the explicit articulation of the connections between the theories and speculative design, as well as in the development and refinement of the post-anthropocentric principles that ground the SEF. As illustrated in Figure 12, the framework does not emerge from a linear sequence but from a continuous process of adjustment, critique, and theoretical reconciliation, carried out through progressive refinement until reaching the current model.

The current model of the SEF was developed to foster critical engagement with the possible futures of sociotechnical networks while guiding interventions that are sensitive to the ethical, social, and material impacts of technology. The three fundamental questions that structure the SEF, presented in Figure 14, constitute its conceptual axis and guide the process of speculation and the planning of interventions. They function as catalysts for reflection, enabling the situating of the present, the imagining of alternative futures, and the projection of possible pathways for transformation.

Figure 14: Diagram of the Three Fundamental Questions.



Source: Author's elaboration.

These questions derive from and expand principles found in strategic foresight methodologies, such as the *Futures Triangle* model (Cruz *et al.*, 2023), while incorporating a sociotechnical and post-anthropocentric perspective that recognizes the entanglement of humans, technologies, and institutions in the co-construction of possible futures.

This dissertation does not seek to disregard the relevance of other design approaches, such as Human-Centered Design (HCD) (Aitken *et al.*, 2025), which aim to deeply understand user needs and contexts, promoting the co-creation of social and economic value. However, what is argued here is that the challenges of the Anthropocene demand a broader scale and scope that exceed human-centered paradigms.

The question **“Where are we?”** situates the present from a relational perspective. Instead of relying solely on a human-centered view, it adopts an approach grounded in sociotechnical networks and entangled ecologies. It is informed not only by objective reality but also by speculative mechanisms of subjectivation that contribute to understanding that reality.

The question **“Where are we heading?”** goes beyond the projection of human-centered trends and begins to consider the forces of entanglement, that is, the actants that propel, resist, converge, or diverge in multiple directions. The trends identified during the analysis of the previous question are understood as emergent effects of the mapped relations rather than as external vectors acting upon the system.

Finally, the question **“Where do we want to go?”** is reformulated not as an aspiration belonging exclusively to humans but as a design problem guided by post-anthropocentric values, in which the projected world must reflect an ethic of shared responsibility among humans and non-humans in the transformation of sociotechnical systems.

In many contexts, the future projected by trends coincides with the desired future, especially when present signals point toward directions that align with ethical values. This convergence, however, is not guaranteed. When emerging trajectories suggest undesirable futures or ones that conflict with post-anthropocentric principles, deliberate intervention becomes necessary to reorient these transformations.

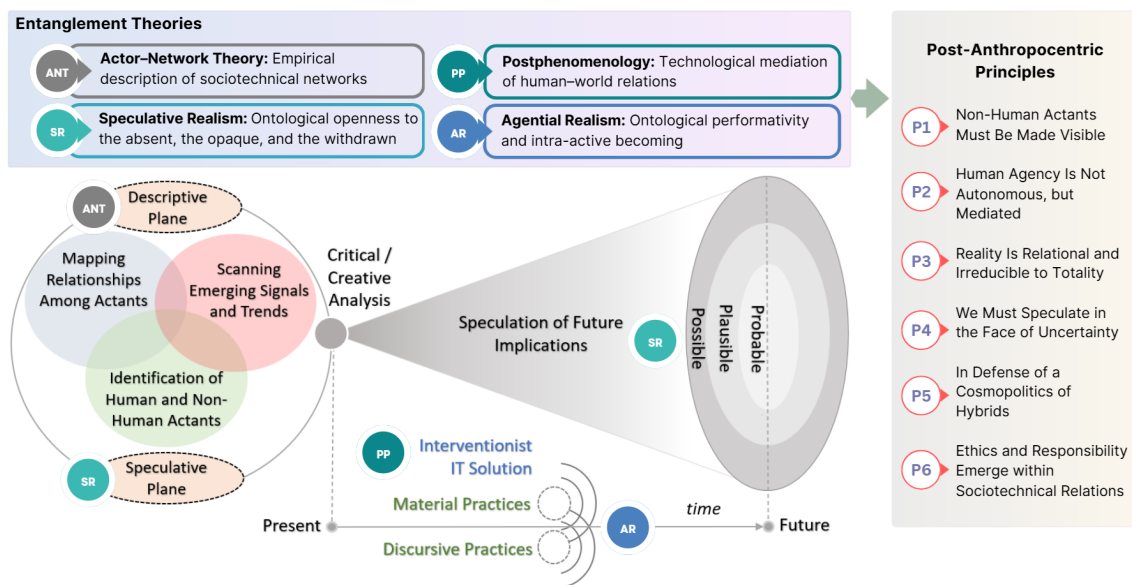
In this scenario, the SEF and its principles align with MtHD (Giaccardi *et al.*, 2025). This perspective conceives design as a relational, distributed, and situated practice embedded within sociotechnical and ecological networks. Although Giaccardi *et al.* (2025) offer a robust theoretical foundation for MtHD, emphasizing entanglement, distributed agency, and the critical examination of representation and responsibility, they do not propose a prescriptive model or methodological framework.

It is precisely at this point that the SEF positions itself. Its contribution lies in simplifying and operationalizing the dense set of Entanglement Theories which, despite their differences, converge by problematizing more-than-human relations. These contributions are synthesized into the post-anthropocentric principles, which function as a conceptual filter that makes them applicable to the design process. Based on this filter, the SEF articulates theoretical foundations with Speculative Design tools, offering a structured pathway for transforming the ontological and epistemological principles of MtHD into design practice. The SEF is illustrated in Figure 15.

At the top of the framework are the main Entanglement Theories that inform its construction. These theories enabled the formulation of the post-anthropocentric principles discussed earlier, which served as the conceptual foundation for developing the design tools described in Section 5. The circular arrangement of each theory within the SEF space indicates where its influence is more pronounced; even so, all theories traverse the model transversally, permeating the SEF as a whole.

Taking the three central questions as structural anchors, the first question, “Where are we?”, is represented by the leftmost circle. The inner subcircles reflect the influence of ANT and Speculative Realism, which inform both the identification and the tracing of actants within the sociotechnical network. These theories support the collection of

Figure 15: Sociotechnical Entanglement Framework (SEF).



Source: Author's elaboration.

objective evidence based on observable behaviors, as well as the speculative interpretation of uncertain or hidden aspects of reality, filling gaps and exploring zones of uncertainty.

From this initial mapping, the model advances toward the identification of emerging trends, integrating objective data with speculative inferences. The Futures Cone opens in the second stage, “Where are we heading?”. At this point, the analysis expands to examine multiple domains of impact, critically exploring the potential future implications of sociotechnical networks should current trajectories materialize. Speculative Realism continues to serve as the primary theoretical basis, supporting the exploration of contingent, uncertain, and non-linear futures.

The tools used in this stage operate through a “cosmopolitics of hybrids,” recognizing the diversity of actants and the different ways in which they may be affected. The future is not uniform; it unfolds asymmetrically across different domains of life, requiring an approach that is sensitive to variations and to the power dynamics that emerge from the sociotechnical entanglement.

The third question, “Where do we want to go?”, is not simply about expressing aspirations; it represents a political stance toward the future. It calls for a socially conscious approach to the design of technologies, one that recognizes their mediating role in shaping relations between humans and the world. The introduction of a new technology in a speculative scenario raises fundamental questions: Which relations does it activate or transform? How does it relate to other actants in shaping a desirable future? Which ethical tensions emerge from this new configuration? In what ways does the technology shape us? And how do we distribute responsibilities to ensure the realization of this desired future?

In this stage, Postphenomenology and Agential Realism become central, providing conceptual tools for analyzing the designed artifact, its enactments in the world, and the

multiple perspectives from which its impacts can be understood. These theoretical lenses enable a diffractive reading of sociotechnical relations (represented by waves that form interference patterns), which recognizes situated, plural, and overlapping points of view. This perspective is aligned with the work of [Rieder *et al.* \(2024\)](#), who emphasizes enactment as the moment in which models come to life, bringing together theory and practice, projection and explanation. This articulation allows for critical engagement with the moral values embedded in design choices and with the modes of distributing responsibilities among the involved actants.

Furthermore, both the interventionist solution and the diffractive analysis are not necessarily anchored in the present; they may be projected to operate within speculated futures. Through agential cuts, it becomes possible to configure material and discursive practices that reconfigure sociotechnical relations, ethically orienting them toward desirable futures. As represented in the lower right portion of the SEF, these practices are supported by the lenses of Postphenomenology and Agential Realism, which expand the scope of design beyond technical functionality by activating the performativity of artifacts in the world.

4.6 Final Considerations of the Chapter

This chapter consolidated the theoretical integration necessary to support the development of the SEF. By comparing different Entanglement Theories and demonstrating their complementarity, the chapter showed that distributed agency, the materiality of relations, ontological uncertainty, and the performative character of reality constitute essential elements for a post-anthropocentric design approach.

Furthermore, the redefinition of sociotechnical networks presented in this chapter demonstrated that understanding technological ecosystems requires going beyond the description of existing associations, as proposed by ANT. It requires incorporating the ontological recognition of withdrawn entities (from OOO), the performativity of relations (from Agential Realism), and the constitutive mediation of artifacts (from Postphenomenology). In this sense, the SEF assumes that sociotechnical networks are not merely observable arrangements but compositions in continuous becoming, in which potential, absent, or not-yet-manifest relations also operate in the production of the real. Introducing speculation into this process expands the very notion of the network. To speculate is not to project fantasies but to illuminate zones of indeterminacy, explore latent possibilities, and make visible forces and actants that do not fully emerge in empirical observation.

The formulation of the post-anthropocentric principles represented a decisive step in transforming complex theoretical foundations into clear guidelines for the practice of Speculative Design. These principles function as a cohesive set of directives that supports the creation of responsible, ethical futures that are attentive to implicated materialities. By presenting the process of conception and refinement of the SEF, the chapter made explicit how theory, critical reflection, and speculative practice converge in the development of this framework.

5. Sociotechnical Entanglement Toolkit

This chapter presents the tools that operationalize the SEF, translating its post-anthropocentric principles into concrete instruments for mapping, speculation, and intervention in sociotechnical ecosystems. After consolidating the conceptual architecture of the framework in the previous chapter, this chapter focuses on its practical dimension, demonstrating how each tool supports speculative design processes informed by Entanglement Theories.

The chapter provides a detailed description of five main tools: the Sociotechnical Board, which supports the ontographic mapping of actants; the Sociotechnical Implications Wheel, which reveals the effects of trends should they materialize in the future; the Possibilities Wheel, which explores the degrees of tangibility of future implications; the Technological Mediation Cards, which introduce philosophical provocations informed by Postphenomenology; and the set of Support Notebooks, which systematize records, data, and reflections throughout the workshops. Each tool is presented in terms of its conception, purpose, associated theoretical principles, and integration within the SEF, indicating how they operate in an articulated manner within the design process.

5.1 Contextualization

To support the operationalization of the SEF, a set of tools was developed based on the post-anthropocentric principles presented in Chapter 4. These tools were designed to function in an articulated manner within the framework, supporting the mapping of sociotechnical relations, the analysis of mediations, and the speculation of futures. Despite this internal integration, each tool retains sufficient autonomy to be used independently or combined with other design approaches, which expands its applicability across different contexts.

All tools are reconfigurable and may be adjusted according to the workshop context, the topic under investigation, or the learning objectives. Likewise, the SEF itself is not closed or rigid. Its architecture allows for the incorporation of new tools, variations, or extensions that deepen specific dimensions of speculative design while maintaining coherence with its post-anthropocentric principles. The complete set of tools is available in the Zenodo repository¹.

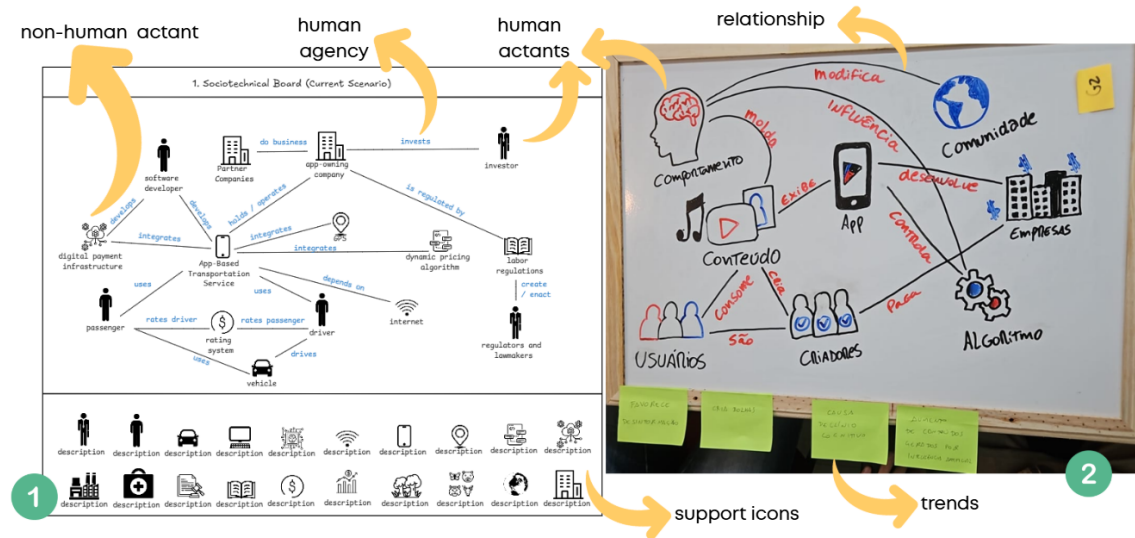
5.2 Sociotechnical Board: An Ontographic Mapping of Actants

The Sociotechnical Board (Figure 16) serves as the starting point for the Speculative Design process informed by entanglement theories. It is a tool designed to map the

¹Zenodo repository link for the Tools: [<https://doi.org/10.5281/zenodo.17824779>](https://doi.org/10.5281/zenodo.17824779)

current sociotechnical ecosystem based on an entry point that may take various forms: a brief description of the scenario under analysis, a research topic, the state of the art of an emerging technology, an organizational process, a public policy, or any other element that can function as an initial anchor for the analysis. From this starting point, the Board enables the identification, positioning, and interrelation of the multiple actants that compose the network, revealing the interactions, mediations, and controversies that structure the environment under examination.

Figure 16: Representations of the Sociotechnical Board: (1) digital version and (2) physical version.



Source: Author's elaboration.

On the left (1) is the digital version of the Sociotechnical Board, created using the Excalidraw tool². Icons representing actants were introduced to facilitate the visual construction of relations within the sociotechnical ecosystem. On the right (2) is the physical version of the board used in in-person workshops. Participants manually draw the actants and trace lines with different meanings (such as influence, modification, or dependency), fostering collective engagement and creative expression. Post-its are added to record trends in the current scenario.

The Sociotechnical Board goes beyond the traditional descriptive orientation of ANT. It incorporates a speculative layer informed by the concept of ontography³ developed by Bogost (2012), expanding the reflective space through which actants are connected. While ANT seeks to rigorously document mediations and associations, ontography offers a more open and creative approach to mapping the world, an act of listing or arranging entities in ways that expose their parallel existence without subordinating them to hierarchical structures or causal narratives. This practice emphasizes the coexistence and divergence among actants, making visible both the couplings and the gaps that constitute the ecosystem.

²Excalidraw link: <https://excalidraw.com/>

³Ontography is a mapping and descriptive practice that reveals the plurality of modes of being, rejecting linear or hierarchical explanations centered on the human and highlighting the entanglement of entities that coexist, even when they often remain opaque to one another.

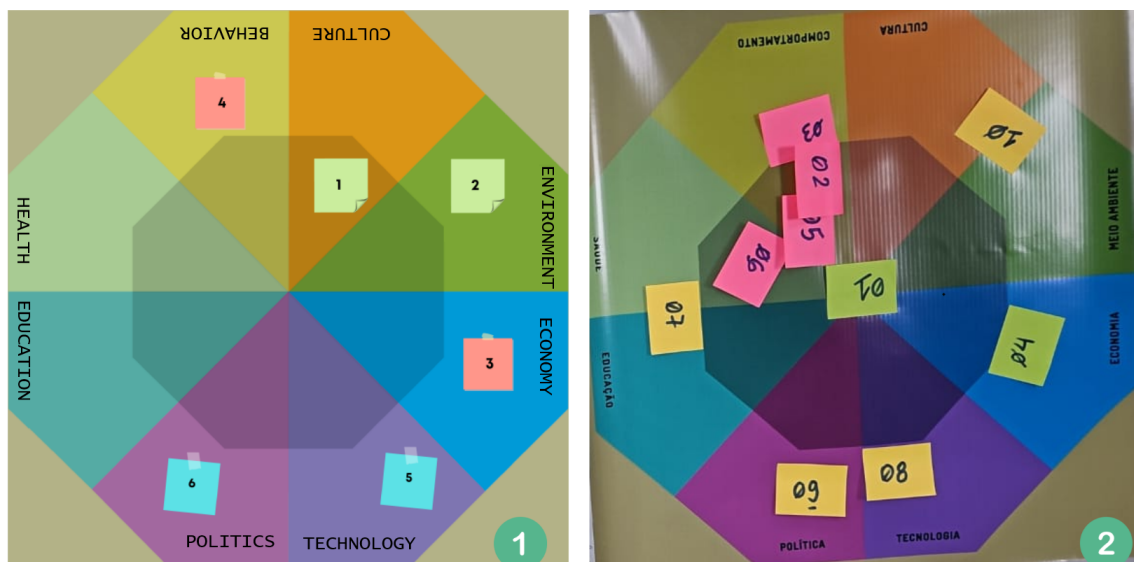
The ontographic approach values the idea that it is not necessary to exhaustively explain how elements relate but rather to reveal them in their singularity and allow their juxtaposition to invite speculation. Speculation in this context is not a matter of guessing but a way of imagining new arrangements, tensions, alliances, and conflicts within the sociotechnical ecosystem.

In this way, the Sociotechnical Board challenges a persistent belief in modern science, criticized by authors such as [Petronio \(2023\)](#), which assumes that a phenomenon can only be understood when all its variables are known and controlled. This logic, rooted in reductionism and inductivism, ignores the contingent, emergent, and relational character of phenomena. Understanding does not require totalization but rather the recognition of situated relations between heterogeneous elements. The Board operates with a form of situated rationality that values incompleteness not as a failure but as an epistemological condition and a driver for creative speculation.

5.3 Sociotechnical Implications Wheel: Recognizing Modes of Existence

The Sociotechnical Implications Wheel (Figure 17) is a tool designed to support the critical analysis of long-term impacts resulting from the introduction of new technologies into complex ecosystems. It invites designers to reflect on the potential developments associated with the previously mapped sociotechnical scenario, considering both positive and negative implications, as well as those deemed desirable. These records are organized in the Support Notebooks.

Figure 17: Representations of the Sociotechnical Implications Wheel: (1) digital version and (2) physical version.



Source: Author's elaboration.

The tool organizes the projected effects of a proposition across eight categories: health, behavior, culture, environment, economy, technology, politics, and education. In the visualization of the wheel, the darker area represents implications already underway,

while the lighter area indicates implications that will occur in the speculated future.

The tool adopts an oligoptic approach, in the terms of Latour e Hermant (2006), by privileging a localized and situated perspective in contrast to Foucault's panoptic view, which presupposes centralized surveillance and hierarchical control. Rather than organizing information in a vertical and centralized manner, the tool proposes a shared framework that is symmetrically accessible to all participants (designers). This is reflected both in the circular layout of the wheel and in the textual structure of the categories, which avoids visual hierarchies and fosters an environment of horizontal and symmetrically distributed observation.

The inspiration for the development of the Sociotechnical Implications Wheel resonates with the project *An Inquiry into Modes of Existence* (AIME) by Latour (2013). The Modes of Existence constitute a philosophical continuation of ANT, deepening its foundations. While ANT is dedicated to the empirical description of associations among actants in sociotechnical networks, rejecting essentialist explanations and classical dichotomies, the AIME project expands this effort by proposing a plural vision of the world that seeks to map the different regimes of veridiction that sustain human practices, such as law [LAW], technology [TEC], religion [REL], politics [POL], and metamorphosis [MET]. It also recognizes that each regime operates with its own conditions of validity, forms of continuity, and risks of failure. Thus, AIME does not abandon ANT but radicalizes it by proposing an ontological diplomacy among distinct modes of existence, moving beyond the modern view that presupposed a single plane of reality.

It is precisely at this point that the radicalization between the two projects takes place. If ANT was already critical of the modern project for dissolving the boundaries between nature and society, AIME goes further by dissolving the very idea of a single plane of reality within which all practices should be evaluated. In the scope of AIME, there is no single, universal regime of truth or legitimacy, but a plurality of modes that coexist, each with its own internal logic. Evaluating a practice requires understanding it within the regime that makes it possible. When the criteria of one mode are applied inappropriately to another, a category error occurs. For example, legislating on the basis of religious dogma means judging the political mode through the lens of religion, which compromises the legitimacy of the practice and generates what Latour calls ontological unhappiness. Conversely, the happiness of a mode emerges when it operates according to its own conditions of existence and is recognized on its own terms.

Just as the AIME project recognizes the existence of multiple regimes of veridiction that sustain different modes of existence, the Sociotechnical Implications Wheel is grounded in the principle that the future should not be understood as a single and predetermined path. It invites designers to critically reflect on long-term implications associated with the previously mapped sociotechnical scenario, considering the possible developments that may emerge if the identified trends materialize. These developments may be positive, negative, or desirable, and are recorded by participants in the Support Notebooks. In the visualization of the wheel, the level of criticality of each implication is represented by a color gradient: the darker region indicates higher criticality associated with that dimension, whereas the lighter region indicates lower criticality. This assessment is typically carried out collaboratively by participants and may be

complemented by additional attributes, such as classification and magnitude of impact for each implication, which can be configured in the Support Notebooks.

Although the wheel does not establish a direct correspondence with AIME, it was designed to make visible the different regimes of validity activated by future scenarios. Drawing on [Kelty \(2023\)](#), it becomes clear that the proposal of modes of existence is a pragmatic attempt to respond to the collapse of modern guarantees of truth. This collapse manifests in the growing difficulty of establishing consensus on what counts as valid, legitimate, or true in societies marked by fake news, informational bubbles on social media, conspiracy theories, and dystopian narratives that compete with traditional scientific and political discourse. In this context of “post-truth,” different social groups come to operate with their own criteria of validity, whether religious, technical, legal, or media-based, often incompatible with one another. The Sociotechnical Implications Wheel addresses this landscape by mirroring these plural logics in its categories. As such, the tool functions as a situated device of composition, one that does not seek to impose a universal validation but instead fosters articulations among different modes of existence. By supporting a distributed and relational reading of future implications, the Wheel promotes more ethical, plural, and responsive decision-making processes that are attuned to the ontological disputes characterizing contemporary sociotechnical ecosystems.

Even though the tool does not explicitly name the modes of existence from AIME, certain analogies can be drawn. The category of Education, for instance, may involve the activation of the modes of Habit [HAB] and Morality [MOR], since educating involves the internalization of norms, practices, and forms of social life. Habits are continuously formed and reformulated, and morality is expressed in the ethical decisions individuals learn to make.

In the case of the Technology category, the modes of Technique [TEC] and Proposition [PRE] stand out. The [TEC] mode refers not only to the presence of material artifacts but also to the chain of mediations that sustain technical efficacy, anchored in sequences of proofs, tests, and stabilizations. However, as argued by [Cellard \(2022\)](#), this mode is often misunderstood when algorithms, as technical entities, are approached exclusively through an instrumental logic. By proposing that algorithms be understood as sociotechnical constructions that circulate across different regimes of meaning, the author reinforces the need to consider how the [TEC] mode is mobilized in association with other regimes, such as the political, legal, or media domains, each attributing different possible existences to technologies. Understanding [TEC], therefore, requires attention to the specific forms of enunciation and validation of this domain, as well as to its constant hybridization with other modes.

In this sense, the Proposition [PRE] mode makes it possible to grasp how technologies are incorporated into everyday practices not merely as neutral instruments but as ontological mediators that reconfigure ways of living and perceiving the world. Moreover, the speculative process itself regarding technological developments activates modes such as Fiction [FIC], which sustains imaginative elaborations of possible futures, and Morality [MOR], which guides judgments about what is desirable, just, or responsible.

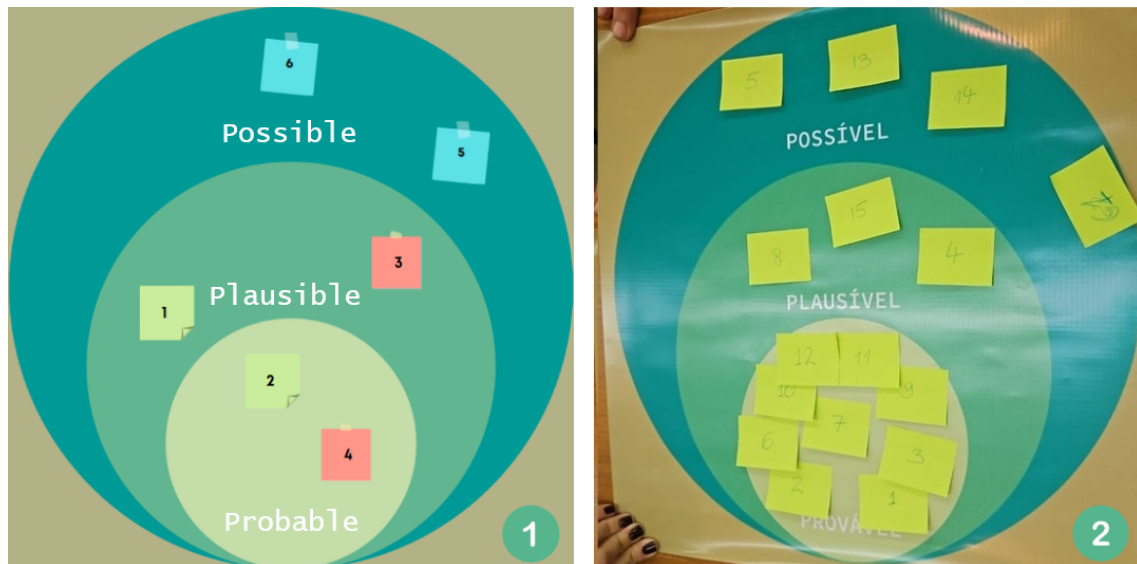
Although the Sociotechnical Implications Wheel has been predominantly applied in

its physical version, adaptations have also been developed for specific contexts, such as remote workshops. In these cases, the tool was implemented in the Excalidraw environment, enabling real-time collaborative completion during synchronous online activities.

5.4 Possibilities Wheel: Exploring the Tangibility of Futures

The Possibilities Wheel (Figure 18) is a tool derived from the Futures Cone (Voros, 2003; Voros, 2017), which is frequently employed in Speculative Design. However, in contrast to the linear and universalizing structure of the traditional cone, which has been criticized for reifying a singular present and suppressing plural temporalities (Forlano; Halpern, 2023), the wheel proposes a more situated, relational, and politically engaged reinterpretation of future making.

Figure 18: Representations of the Possibilities Wheel: (1) digital version and (2) physical version.



Source: Author's elaboration.

This tool is used in a complementary manner to the Sociotechnical Implications Wheel, which is responsible for identifying, from a speculated scenario, the desirable and undesirable implications in different areas of everyday life, such as education, work, health, and culture. The Possibilities Wheel, in turn, organizes these implications according to their degree of possibility, distributing them into concentric zones that represent different levels of likelihood: probable, plausible, and possible.

The complementarity between the two wheels is anchored in an earlier stage of the speculative process in which the current sociotechnical ecosystem is mapped and trends are identified. At this stage, there is an explicit invitation to include a wide diversity of actants, particularly those traditionally excluded or rendered invisible. This practice supports the emergence of more plural futures from the outset, mitigating the problem of the Futures Cone, which assumes a single point of departure and overlooks multiple

temporalities (Forlano; Halpern, 2023).

Furthermore, the Possibilities Wheel seeks to overcome the temporal linearity and technoprogressive bias characteristic of the Futures Cone, which, according to Forlano e Halpern (2023), is rooted in a Western ontology of time that marginalizes pluritemporal or non-linear conceptions. The possibility of constructing multiple instances of the wheel, either from the same starting point or from distinct points, allows for the coexistence of diverse, simultaneous, and entangled futures. When articulated with other tools and guided by post-anthropocentric principles, this tool supports the incorporation of non-hegemonic worldviews and decolonial epistemologies. This orientation broadens the interpretive spectrum of the speculated scenarios and makes visible the plurality of perspectives on what is possible, desirable, or feared.

The tool also mitigates the issue of the supposed neutrality of the Futures Cone (Forlano; Halpern, 2023) by grounding itself in the implications identified from the experiences, values, and perspectives of the designers. Instead of suggesting a technically manageable or neutral future trajectory, the tool makes explicit the ethical and political dimensions of design choices, inviting the designer to take an active stance toward potential future developments. It guides strategic decisions and project interventions by fostering reflection on how to increase the likelihood of desirable implications while simultaneously reducing the likelihood of undesirable ones. In this way, the tool functions as a tactical guide for reconfiguring the sociotechnical ecosystem, whether through the introduction of specific technologies or through other forms of intervention such as public policies, institutional changes, process reorganization, or governance strategies. By making visible the possible pathways for approaching desirable futures, the wheel supports decisions aimed at sociotechnical transformation in a situated and context-responsive manner.

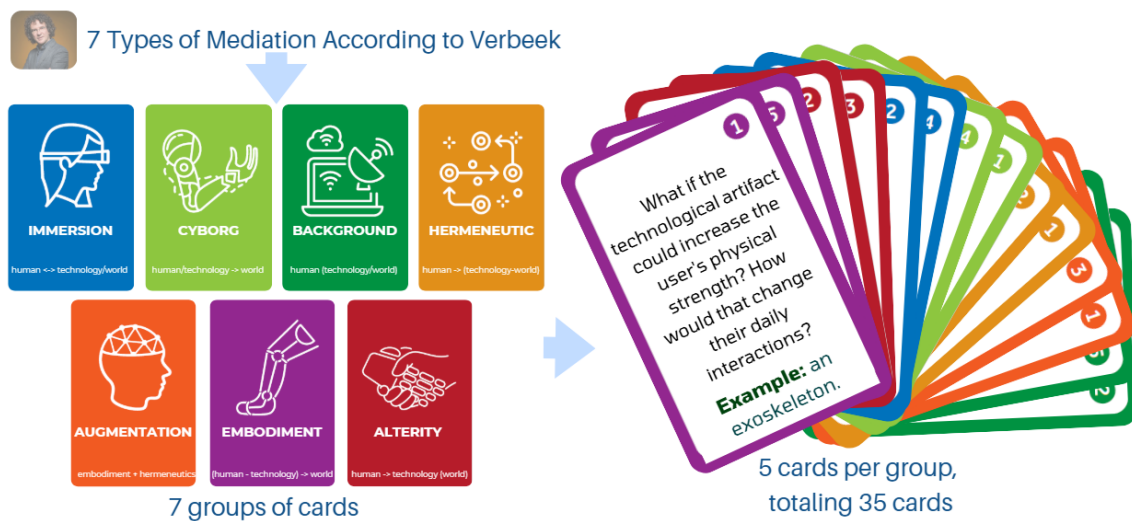
For this reason, its application is useful both in preliminary stages, as a support for defining strategies and design directions, and after the intervention, allowing speculation on how the sociotechnical network could be transformed to maximize the realization of more desirable futures. In this way, the Possibilities Wheel replaces the idea of passive projection with an active and situated stance, bringing together speculation and responsibility in a continuous exercise of negotiating possibilities, values, and consequences.

5.5 Technological Mediation Cards: Speculative Provocations Informed by Postphenomenology

The Technological Mediation Cards (Figure 19) were developed to support designers in the critical analysis and creative exploration of the relationships between humans, technologies, and the world. Grounded in Verbeek's TTM (Verbeek, 2005b), this tool aims to foster speculative and reflective processes concerning the multiple ways in which technologies shape, reconfigure, and transform human practices, perceptions, and experiences.

The cards are based on the understanding that technologies are not mere instruments but mediating agents that actively participate in the constitution of relationships between

Figure 19: Cartas de Mediação Tecnológica.



Fonte: Elaboração própria.

humans and the world.

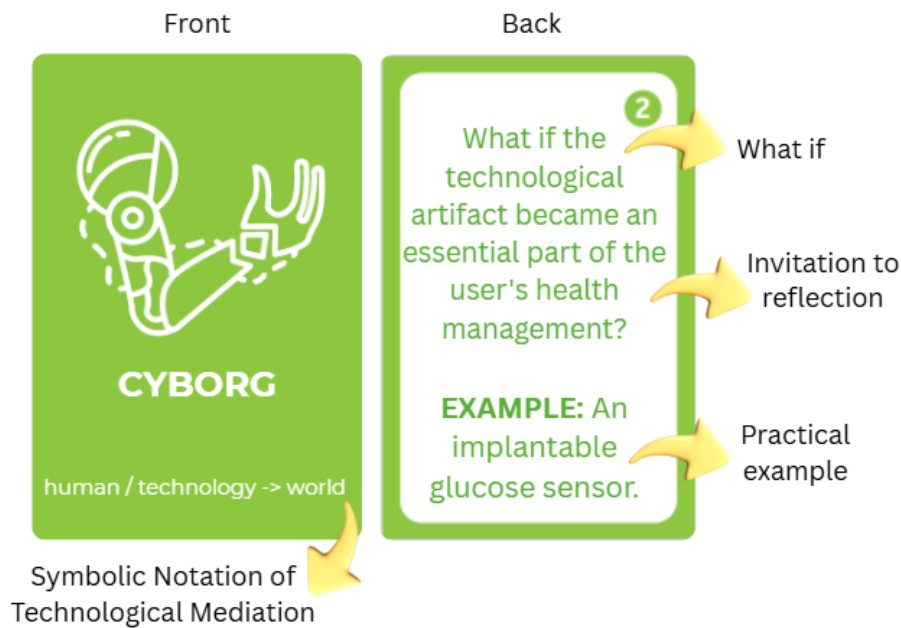
Verbeek (2005b) describes seven distinct types of technologically mediated relations: “embodiment,” “hermeneutic,” “alterity,” “background,” “cyborg,” “augmentation,” and “immersion.” Each mode describes a specific form of mediation, revealing how technologies become extensions of the body, interpret the world, take on characteristics of otherness, operate in the background, integrate with bodies as cyborgs, expand capabilities, or configure immersive environments that reconfigure perception, action, and experience in the world.

The tool consists of five numbered cards for each of the seven modes of technological mediation proposed by Verbeek (2005b). Each card (Figure 20) presents, on its front side, a speculative question beginning with “What if...,” which serves as an invitation to critical reflection on possible futures mediated by technologies. This question is aligned with one of the types of technological mediation identified by Verbeek. Below the question, a practical example illustrates the proposed situation. On the reverse side of the card, there is a graphical representation of the corresponding mediation type, accompanied by its symbolic notation, which synthesizes the relationship between human, technology, and world in that specific mode of mediation.

They were designed to support two complementary movements in the design process. On the one hand, they function as instruments of speculative exploration, enabling the imagination of new technological possibilities that go beyond conventional functionalities by focusing on the mediations and transformations that such technologies may produce in the relationships between humans and the world. On the other hand, they operate as a tool for critical phenomenological analysis, guiding the assessment of existing technologies or even of the speculated ones, encouraging deeper reflection on how these artifacts shape and reconfigure experiences and practices in the current or speculated sociotechnical network.

In the digital format, the cards are presented in an interactive carousel; when clicked,

Figure 20: Cyborg Card: front and back.



Source: Author's elaboration.

they randomly reveal one of five questions on the reverse side. The introduction of randomness is not merely a technical choice but a fundamental methodological strategy. It operates as a “speculation pump”⁴ (Oulasvirta; Hornbæk, 2022), which disrupts linear and predictable sequences of reasoning, encouraging interpretive surprises and unplanned associations. In doing so, it expands the space of possibilities and fuels the critical dimension of Speculative Design.

It is important to emphasize that there is no fixed script for using the cards. The mode of application may vary according to the workshop context, the time available for the activity, the profile of the participants, and the objectives of the design process. For example, in activities with limited time, one may choose to explore only a subset of mediation types or to distribute different cards among participants to enable a more distributed analysis. In more extensive contexts, the cards can be used in depth, presenting different mediations around the same artifact. The management of this dynamic is flexible and can be handled either by the working groups themselves or by facilitators, who may reorganize the cards as needed to support the fluidity and productivity of collective reflection.

The Technological Mediation Cards are available in different formats to facilitate their adoption in diverse contexts. The initial versions were printed, but in subsequent iterations, the development of digital versions was prioritized: one as an Android application and another accessible via web browser. This allows participants to interact with the tool through mobile devices in both synchronous and asynchronous activities.

⁴The expression “speculation pump” refers to a theory or tool that functions as a speculative engine, prompting the designer to imagine propositions such as: “if the design were like this, then the interaction would unfold in that way.”

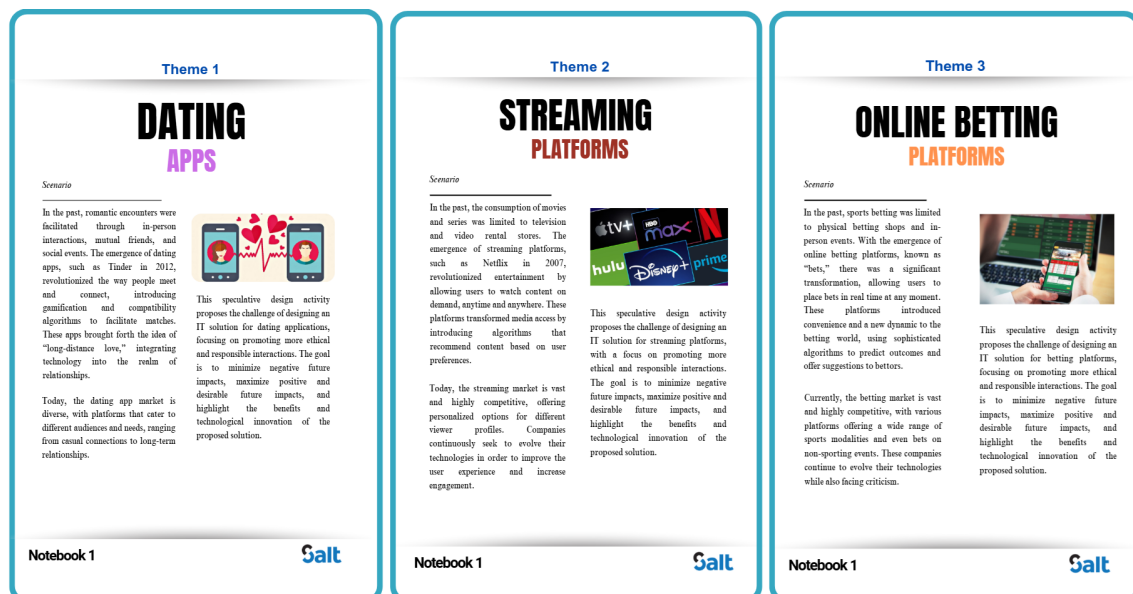
5.6 Tools for Documentation, Data Collection, and Systematization

The Support Notebooks are tools that assist in documenting and collecting data generated through the main tools employed in the process. They are adaptable and situated resources that can take on different formats and functions depending on the focus of the workshop, the profile of the participants, or the objectives of the speculative process. They may be renamed, combined, or subdivided, adjusting to the application context and to the tools used. In the present workshop, five distinct notebooks were used, each aligned with a specific stage of the process:

5.6.1 Support Notebook 1

This notebook, illustrated in Figure 21, provides an initial set of themes that serve as a starting point for the groups' investigative process.

Figure 21: Notebook 1 with initial themes to activate speculation.



Source: Author's elaboration.

In the IHC 2024 workshop, this support notebook presented a set of six themes: “Dating Apps,” “Streaming Platforms,” “Online Betting Platforms,” “Short-Video Platforms,” “Online Learning Platforms,” and “Circular Economy Platforms.” This notebook functions as a device for activating the speculative process. Each theme presented in the notebook serves as a starting point for speculation, encouraging participants to begin their trajectory from an element that evokes reflection, doubt, or curiosity.

5.6.2 Support Notebook 2

This notebook, illustrated in Figure 22, assists in systematizing the identified implications by numbering and listing them, serving as support for both the

Sociotechnical Implications Wheel and the Possibilities Wheel.

Figure 22: Notebook 2 used for organizing and classifying implications.

The current sociotechnical ecosystem presents trends that, if confirmed by the speculated date, will generate implications. Develop a list of these implications, considering the possible impacts resulting from the consolidation of these trends in the future.

ID	Implication	Classification	Magnitude

Group:

Speculated Date:

The **classification** categorizes each implication as *positive*, *negative*, or *desirable*.

The **magnitude** categorizes the degree of impact, which may be *low*, *medium*, or *high*.

Activity Flow

1. theme selection
2. Ecosystem Modeling
3. Implications Wheel
4. Possibilities Wheel
5. Solution Design
6. Future Narrative
7. Responsibility Frame
8. Presentation

Source: Author's elaboration.

In this notebook, participants classify each implication as positive, negative, or desirable, and indicate the perceived magnitude of its impact, categorized as low, medium, or high. This structure facilitates critical analysis and the definition of priorities, allowing participants to reflect on the most effective strategies for mitigating undesirable impacts and enhancing desirable developments throughout the speculative process.

5.6.3 Support Notebook 3

Support Notebook 3 serves as a space for documenting the reflections generated from the exploration of the Technological Mediation Cards and from the conception of the interventionist IT solution within the speculated future scenario. Depending on the workshop context, this notebook, illustrated in Figure 23, can be adapted either for the critical evaluation of existing technologies or for the speculation of new forms of mediation in imagined technological solutions.

As participants interact with the cards, they are invited to reflect on how technologies shape, reconfigure, or expand the relationships between humans and the world. What is recorded in the notebook is the set of reflections generated by the group in relation to each set of specific mediation cards. These notes should capture the identified modes of mediation, their possible effects, the characteristics of the technological artifact, and the

Figure 23: Notebook 3 for supporting reflections on technological mediations.

Notebook 3

Group: _____

1. Access the Technological Mediation Cards using the QR code below.

2. Use the Cards to explore different perspectives and stimulate the creation of innovative solutions.

3. After exploring the Technological Mediation Cards, record in the corresponding field the ideas developed for each type of relation.

NOTE: The speculative solutions do not need to be incorporated into the final design, but they are essential for fostering new possibilities.

page 1 of 3

Notebook 3

Describe the Technological Solution. It is worth noting that using the results from the mediation cards is not mandatory.

Group: _____

Activity Flow

- 1. theme selection
- 2. Ecosystem Modeling
- 3. Implications Wheel
- 4. Possibilities Wheel
- 5. Solution Design
- 6. Future Narrative
- 7. Responsibility Frame
- 8. Presentation

page 2 of 3

Notebook 3

Describe how the solution maximizes positive and desirable implications and minimizes negative ones.

Group: _____

Implication ID	Solution for the implication

page 3 of 3

Source: Author's elaboration.

associated dilemmas. The notebook also includes a page for sketching and describing the IT proposal, as well as a synthesis of how the proposed solution intends to mitigate or enhance the implications recorded in Support Notebook 2.

5.6.4 Support Notebook 4

This notebook, illustrated in Figure 24, guides the creation of futuristic narratives that explore the use of the technology described in Support Notebook 3. The futuristic narrative includes human personas and non-human entities, drawing inspiration from practices such as those presented by Chen e Pschetz (2024). The goal is to give form and context to the effects of the interventionist technological solution by staging how the technology reconfigures the world around it through diverse voices, which may include algorithms, sensors, legislation, animals, cities, or institutions. This approach aligns with Design Fiction (Stead; Coulton, 2022; Rajcic; McCormack, 2023), which aims to make alternative futures tangible through narrative, visual, or textual artifacts that provoke critical reflection on sociotechnical values and consequences.

Support Notebook 4 also engages with Speculative Fabulation, a performative practice inspired by Donna Haraway's philosophy Haraway (2013), as explored by Søndergaard *et al.* (2023) and Stead e Coulton (2022). In this approach, speculative narratives break with linear logics and traditional hierarchies of agency, destabilizing normativities and bringing together emerging actors and hybrid sociotechnical configurations in which humans and non-humans share responsibilities in the co-constitution of possible futures.

Figure 24: Notebook 4 as a tool for staging situated futuristic narratives.

The group must create a story that includes human or non-human actors that are part of the sociotechnical ecosystem for the speculated date. The narrative should address how the introduced technology minimizes negative impacts and enhances positive impacts, highlighting its benefits and technological innovation.

1. Identification of Actors:
Include human and non-human characters that interact within the future sociotechnical ecosystem. Some of these actors may have been mapped in the “sociotechnical board,” while new actors may have emerged.

2. Relationship between Actors and Technology:
Describe how the different actors use the speculated solution in the future. What are the relationships between the actors and the artifact, and how are these interactions and relationships constructed?

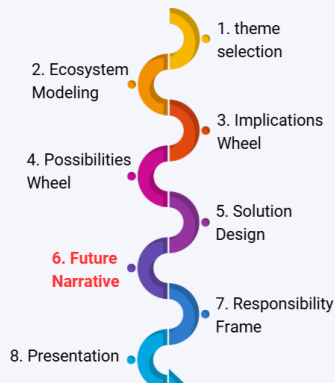
3. Narrative Development:
Choose one actor (human or non-human) and develop the narrative from their point of view. This actor will serve as the guiding thread of the story. Give names to the characters to make the story more engaging and realistic. Specify the time period in which the story takes place, in accordance with the previously speculated scenario. Describe the setting of this period, including social, economic, and environmental aspects.

Notebook 4

Group:

Perspective of which author?

Activity Flow



- 1. theme selection
- 2. Ecosystem Modeling
- 3. Implications Wheel
- 4. Possibilities Wheel
- 5. Solution Design
- 6. Future Narrative
- 7. Responsibility Frame
- 8. Presentation

page 1 of 2



Source: Author’s elaboration.

The activity invites participants to reflect on the impacts of the technology by considering who benefits, who is harmed, and which ways of life are enabled or constrained. When constructing the speculative narrative, the groups must consider the imagined ecosystem, the mapped actors (although not necessarily all of them), and the identified implications, as well as the benefits the technology may offer to mitigate negative impacts and enhance positive ones. The aim is to craft a storyline in which ethics emerges from within the narrative itself as part of the experience rather than as an external or subsequent judgment.

5.6.5 Support Notebook 5

This notebook, illustrated in Figure 25, guides the organization of the responsibilities assigned to the various actors involved, based on the imagined interventionist solution and the speculated futuristic narrative. Its purpose is to support the mitigation of negative implications and the amplification of positive ones.

When completing this notebook, groups are invited to identify responsibilities by considering actors such as developers, users, institutions, algorithms, technical objects, and natural environments. This approach starts from the premise that responsibility is not an isolated choice but emerges from the intra-active relations among people, technologies, institutions, and other non-human entities. This perspective aligns with Agential Realism, according to which ethics and responsibility do not precede relations

Figure 25: Notebook 5 as support for diffractive practice and shared responsibility among actants.

Based on the future narratives developed by the group and on the design of the artifact, assign specific responsibilities to the different actors involved, considering the previously mapped implications.

implication ID	Responsibilities of the actors (May be human or non-human)

page 1 of 1

Notebook 5

Group:

Activity Flow

1. theme selection

2. Ecosystem Modeling

4. Possibilities Wheel

6. Future Narrative

8. Presentation

3. Implications Wheel

5. Solution Design

7. Responsibility Frame

Salt

Source: Author’s elaboration.

but are constituted within the discursive-material practices that mutually connect and transform the elements of a phenomenon (Barad, 2007).

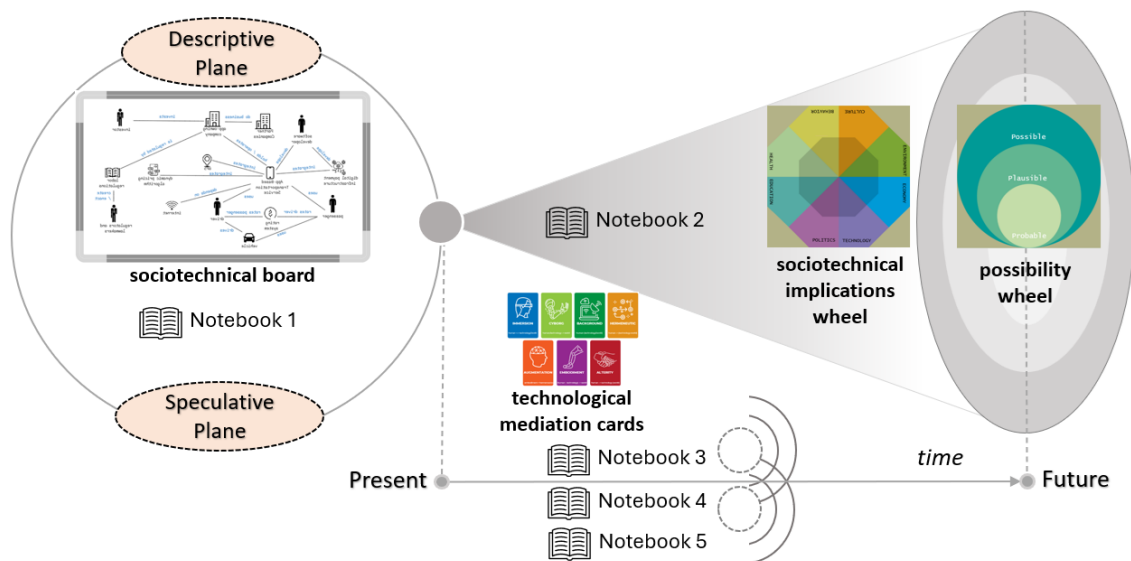
5.6.6 Positioning the Sociotechnical Entanglement Toolkit within the SEF

Figure 26 illustrates how the tools and support notebooks are conceptually and operationally integrated into the SEF framework across the different phases of the speculative process.

To answer the question “Where are we?”, Support Notebook 1 was used as the starting point, and the Sociotechnical Board supported the mapping, discussion, and critical analysis of the ecosystem related to the theme selected in Notebook 1. “Where are we heading?” represents the transition from the present to the future, in which the Sociotechnical Implications Wheel and the Possibilities Wheel are used to speculate about future possibilities based on information drawn from the present. Support Notebook 2 deepens this discussion by classifying these possibilities as positive, negative, or desirable, and by indicating their perceived magnitude.

The question “Where do we want to go?” follows this stage, with the Technological Mediation Cards and Support Notebook 3 guiding the intervention within the speculated future. Support Notebook 4 materializes this future through a fabulation, and Support

Figure 26: Conceptual and Operational Placement of the SEF Toolkit.



Source: Author's elaboration.

Notebook 5 distributes responsibility for this future, aligning the process with a post-anthropocentric perspective.

5.7 Final Considerations of the Chapter

This chapter demonstrated the centrality of the tools in materializing the SEF and showed how post-anthropocentric principles can guide design practices. By presenting each instrument in detail, the chapter highlighted that the Sociotechnical Board expands awareness of actants and relations; that the Implications and Possibilities Wheels enable the exploration of the effects of sociotechnical futures; that the Technological Mediation Cards operate as philosophical triggers for critical reflection; and that the Support Notebooks structure the investigative process, organizing data and sustaining the systematic rigor required for subsequent analysis. These artifacts function as devices of visualization, mediation, and speculation, consolidating the SEF as a practically grounded and theoretically informed approach.

The chapter also emphasized how these tools, when operating in an integrated manner, guide the development of imagined technological solutions while expanding critical awareness of the worlds such solutions may bring into being. They make visible the complexity of sociotechnical ecosystems and reinforce the collective responsibility involved in the futures we choose to design.

6. Methodological Procedures of the Participatory Speculative Design Workshop

This chapter presents the methodological orientation that underpins the Participatory Speculative Design workshop conducted in this research, integrating epistemological foundations, methodological decisions, and the execution procedures adopted throughout the study. It begins with a description of the Entanglement Paradigm as a research orientation, highlighting how this perspective repositions traditional methodological decisions by emphasizing the phenomena, mediations, and intra-actions that constitute the investigative process. The chapter then introduces the participatory design structure that guided the workshop, detailing the ethical and logistical planning, participant selection, materials employed, and the protocol that organizes each stage of the activity. It also describes the instruments used for data collection and systematization, aligning them with the SEF tools and with the analytical needs of the research.

Finally, the chapter presents the analytical methods employed, namely content analysis and diffractive analysis, justifying their compatibility with the Entanglement Paradigm and demonstrating how they enable the interpretation of data in a relational, situated manner that remains attentive to the materialities involved.

6.1 The Entanglement Paradigm as a Research Orientation

This research is anchored in the Entanglement Paradigm, proposed by [Frauenberger \(2019\)](#) as a new theoretical and methodological horizon for HCI, whose scope is here expanded to the field of IS. This paradigm emerges from the recognition that earlier approaches based on cognitivist, empirical or even phenomenological models are no longer sufficient to account for the ontological, epistemological and ethical complexity that characterizes the contemporary world. Table [12](#) presents a comparison between different research paradigms.

The Entanglement Paradigm differs from Positivism and Interpretivism by breaking with the dualisms that sustain these paradigms. In positivism, a form of naive realism prevails, in which reality is understood as external, objective, and accessible through neutral observation. The researcher seeks to describe discrete entities and their causal relations, assuming that knowledge is a faithful representation of the world. Interpretivism, although recognizing the social construction of reality, maintains the centrality of the human subject, assigning interpretation a primary role in the production of meaning. In both cases, the world is conceived as something given; the difference lies only in the way it is accessed.

By contrast, the Entanglement Paradigm proposes a relational and processual realism, in which the world does not pre-exist interactions but emerges through intra-actions ([Barad, 2007](#)). Knowledge is understood as a diffractive rather than representational phenomenon, produced through the agential cuts that configure what becomes relevant in a given context. This paradigm departs from the separation between

Table 12: Comparison across research paradigms.

Dimension	Positivism	Interpretivism	Participatory	Entanglement
Ontology (assumptions about the nature of things)	Naive realism: reality is independent of and prior to human conception, and can be apprehended.	Relativism: multiple realities exist, each co-constructed through social interactions among people and specific environments.	Multiple and participatory realities, co-constructed through interactions between people and environments.	Relational realism: the world does not pre-exist interactions but co-emerges through intra-actions. The real is processual, dynamic, and performative.
Epistemology (assumptions about how things are known)	Reality is knowable through reason and observation. It is possible to obtain singular, independent, factual results, thus universally true.	There is no neutral or objective standpoint from which competing truths can be judged; truth is relative to a perspective.	Knowledge emerges from collaboration and the joint creation of understandings capable of transforming the world.	Knowledge does not mirror the world; it participates in its production. Theory and practice continuously intersect, and the researcher is a constitutive part of the phenomenon.
Methodology (assumptions about how one attempts to know things)	Experimental/manipulative (hypothesis testing). Hypotheses can be verified as true. Quantitative methods and statistical or mathematical representations predominate.	Dialectical or hermeneutic: critical reading of sources to reveal assumptions, implicit messages, and interpret meanings.	Collaborative and action-oriented: reduction of hierarchies between researcher and participant; individual and collective reflection; joint decisions about actions.	Performative and diffractive: the method does not collect data but produces phenomena. Analysis privileges patterns of interference between material and discursive practices.
Axiology (ethics, values, who or what is considered important or relevant)	Knowledge obtained through hypothetico-deductive means is value-free. Those who produce and use such knowledge have privileged access to reality and are seen as objective, neutral, and disinterested.	Valuation is inevitable. The construction process is influenced by the researcher's values and relative to a specific perspective.	All people are considered valuable. Reflexivity, co-created knowledge, and non-Western forms of knowing are valued to avoid oppression and dehumanization.	Ethics is relational and distributed: responsibility is shared among humans and non-humans. The value of research lies in responsible responsiveness (response-ability) to the consequences of intra-actions.

Source: adapted from Malik e Malik (2021) and Frauenberger (2019)

subject and object, theory and practice, or observer and observed. Each act of research is a performative act that reconfigures the world and its possibilities for becoming (Østerlund *et al.*, 2020).

The Entanglement Paradigm partially aligns with the Participatory Paradigm because both share a relational and distributed ethics. Both value the multiplicity of perspectives and the collective creation of meaning. However, entanglement expands this scope by recognizing the material agency of non-humans such as technologies, algorithms, and infrastructures, understanding them as active participants in the constitution of sociotechnical phenomena. Participation therefore becomes a field of co-emergence.

6.2 Participatory Design

Participatory Design (PD) is a methodological approach that involves the active collaboration between researchers and community members or end users during the design process (Chan *et al.*, 2023). Unlike traditional approaches, in which the researcher assumes an external and impartial position, PD recognizes the value of

participants' tacit knowledge and seeks to integrate their perspectives into the collective construction of solutions. This approach emphasizes the co-creation of knowledge, making the design process more inclusive and socially relevant.

For this active collaboration to take place effectively, PD relies on five fundamental principles: Inclusion, Reflection, Playfulness, Empowerment, and Emergence (Slingerland *et al.*, 2022). These principles structure PD practice and directly correspond to the tension patterns identified in Speculative Design (Section 2.6.3), offering ethical and operational guidelines for dealing with tensions inherent to the process. The principle of Inclusion, for instance, aligns with the tension between Human Exclusion and Inclusion by emphasizing the importance of engaging all stakeholders, especially marginalized groups. Reflection responds to the tension between Gains as commercial value or knowledge by promoting the exchange of experiences and mutual learning as legitimate forms of value. Playfulness contributes to addressing the tension between narrative and practical use by creating an environment of creative exploration that allows multiple interpretations of the speculative artifact. Empowerment directly addresses the tension of Engagement by shifting participants from the position of witnesses to active agents in the design process. Finally, Emergence responds to the tension between Conclusion as sketch or finished product by valuing open and adaptable solutions that continue to evolve even after the end of the project.

The scope of PD is expanded when aligned with the Entanglement Paradigm, which broadens the notion of participation beyond the human by incorporating multiple forms of life and materialities into processes of co-emergence. This expansion also brings PD closer to MtHD (Barendregt *et al.*, 2025; Jensen *et al.*, 2025; Nicenboim *et al.*, 2024), since the practice begins to function as a space of ecological mediation in which humans and non-humans, including species, ecosystems, and technological artifacts, participate in the mutual configuration of shared worlds. This shift moves the focus from the “participation of people” to modes of existence oriented toward “being-with,” “becoming-with,” and “living-with” (Light, 2024).

6.3 Participatory Speculative Design Workshops

Participatory Speculative Design (PSD) (Farias *et al.*, 2022; Ye; Zhang, 2024) integrates principles from Speculative Design (Dunne; Raby, 2024) and PD (Chan *et al.*, 2023), bringing together critical imagination and social co-creation. Its focus lies in co-speculation processes in which participants act as co-authors of possible futures, expanding participation, embracing value conflicts, and fostering critical engagement with wicked problems (Ritchey, 2013). PSD acknowledges that participants begin from different worldviews, which enriches the speculations and strengthens the collective construction of scenarios, artifacts and critical analyses of both the imagined futures and the present.

Workshops play a central role in PSD (Clemensen *et al.*, 2025). They function as arenas for negotiating meaning in which technical, organizational and experiential forms of knowledge intertwine to generate solutions situated in social practice. In more-than-human workshops (Light, 2024), this space expands to include non-human entities that

begin to exercise agency within decision-making processes. In this sense, workshops become instruments of ontological and ecological justice, conceiving design as a practice of care and regeneration rather than merely the production of artifacts.

From the perspective of the Entanglement Paradigm, hybridity and the co-constitution of sociotechnical realities emerge together with the workshops rather than in isolation. They integrate a single phenomenon that involves the researcher, the thesis manuscript, the observations of reviewers and the advisor, the participants, the facilitators, the framework and the design tools. All these elements co-emerge and mutually transform one another throughout the investigative and creative process, forming a relational fabric in which knowing, designing and reflecting are inseparable dimensions of the same phenomenological act.

6.4 Empirical Implementation of the SEF: Speculative Design Workshop at IHC 2024

This section presents the detailed description of the workshop titled “Speculative Design: Building Bridges between Technology, Ethics, and Social Inclusion” (Loutfi *et al.*, 2024), held on October 7, 2024, as a workshop at IHC 2024. Structured around the SEF, participants were organized into groups and invited to co-speculate futures, imagine interventionist technologies, and reflect on the shared responsibilities between humans and non-humans.

The goal of the workshop was to provide an experience in which tools, methods and narratives were mobilized to cultivate a responsive stance toward the complexities of the contemporary world. For each specific theme, the workshop sought to develop an understanding of the current ecosystem, a projection of its future through the identification of implications arising from the unfolding scenario, the design of a futuristic technology intended to intervene in that future by mitigating negative effects and amplifying positive ones, a speculative narrative describing the scenario in which the technology is embedded, and finally the distribution of responsibilities among the actants in this future setting.

6.4.1 Workshop Planning Protocol

The workshop planning process followed a protocol grounded in Speculative Design, conceived as a reflective design practice guided by the three fundamental questions that structure the SEF framework.

Where are we now? oriented the diagnostic phase, dedicated to characterizing the workshop context, recognizing the material, human and institutional conditions involved, and defining the resources available. This question carried a dual character: a physical one, considering the fact that the workshop would take place in Brasília while the team was located in Rio de Janeiro, and a technical-instrumental one, involving the verification of equipment, the availability of facilitators, the financial constraints related to travel, and the possibilities for institutional support.

Where are we heading? guided the anticipation of trends and logistical challenges. For example, the impossibility of transporting certain materials, such as the set of sociotechnical boards that would exceed luggage limits, was assessed. This limitation motivated the development of foldable versions and digital alternatives, such as the online and Android-app formats of the Technological Mediation Cards. Considerations were also made regarding the suitability of the physical space and the available time, both of which influenced the final format of the workshop.

Where do we want to go? defined the normative dimension of the protocol, meaning the ethical and political horizon that guided the choices regarding content and method. At this stage, reflections were made on the most relevant themes and concepts, the tools most appropriate for the workshop and their position within the framework, and the type of analysis intended during the activity.

As a result of this protocol, the planning was structured into two main stages: the pre-workshop phase and the workshop itself. The first phase included ethical considerations, the definition of the participant profile, dissemination strategies, and the organization of materials. The second concerned the execution, organized in blocks that balanced theoretical exposition, practical experimentation, and collective discussion.

6.4.2 Pre-Workshop Planning

This stage refers to the planning conducted prior to the execution of the workshop. It includes ethical considerations, the definition of participant roles, and the organization of the materials and tools required.

6.4.2.1 Ethical Considerations

The workshop was reviewed and approved by the Research Ethics Committee (CEP), registered on the Plataforma Brasil system under CAAE number 78782524.8.0000.5285, in accordance with Resolution CNS 510/2016. All ethical procedures were observed, including compliance with the Brazilian General Data Protection Law (LGPD, Law 13.709/2018), ensuring the responsible handling of any personal data collected.

Before the beginning of the activities, it was planned that an Informed Consent Form (TCLE)¹ would be presented and read to the participants, allowing them to ask questions and freely decide whether to participate.

6.4.2.2 Participant Profile

The participation of three types of individuals was planned. The facilitator-presenters were responsible for conducting the central activities, including presenting the core concepts, mediating the final discussions, and defining the timing of each stage. The support facilitators were responsible for distributing the tools, accompanying the groups during the tasks, and clarifying doubts, directing them to the facilitator-presenters when needed. It is important to note that no requirement for advanced knowledge of Speculative Design or Entanglement Theories was established for these support facilitators. Finally, the participants, who constituted the target audience of the

¹TCLE: Termo de Consentimento Livre e Esclarecido

workshop, were expected to carry out the practical activities and produce the results using the tools provided.

For this workshop, the planned team consisted of one facilitator-presenter (the author of this dissertation) and four support facilitators. The number of places for the target audience was limited to forty participants. The planned profile for this group included students, researchers, and professionals in the fields of IT, HCI, and Design, with an interest in exploring Speculative Design methods and developing critical competencies related to reflecting on the impacts and future implications of technologies.

6.4.2.3 Workshop Dissemination

The dissemination of the event was carried out through different channels in order to reach a diverse audience. Initially, the official event website provided detailed information about the workshop. Additionally, the facilitators sent email invitations directly to registered attendees, reinforcing communication and encouraging participation.

Complementing these efforts, promotional videos were produced and shared through the Instagram profile @technofutureslab, an account that remains active and continues to publicize activities and events related to Speculative Design. Specific posts were also published on LinkedIn, expanding the reach of the dissemination among the academic and professional community interested in the topic.

6.4.2.4 Materials and Tools

The planning established that the activities would take place in a room equipped with a projector, a computer, and eight round tables, which would facilitate participant interaction and the collaborative use of the tools. Eight sociotechnical boards printed on white vinyl adhesive (1 m × 1.2 m), eight sociotechnical implications wheels, and eight possibilities wheels (each with an 80 cm diameter) were prepared and printed on canvas. The Technological Mediation Cards were also made available in digital or physical format, according to participant preference. Each group was to receive a kit containing the five support notebooks, printed in A3 format on special colored paper. Additional materials included multicolored Post-its (in square and rectangular formats), pens, pencils, erasers, thick and thin markers in two colors, and erasers for the boards.

Pens, pencils, and erasers were planned to support the use of the support notebooks, since it was expected that participants would record, revise, and rewrite their insights during discussions until reaching consensus.

The colored Post-its were designated for use on the Sociotechnical Board and on the Sociotechnical Implications and Possibilities Wheels. Larger Post-its were intended to record trends around the Sociotechnical Board, while smaller ones were allocated for numbering the future implications displayed on the wheels, in alignment with the records made in Support Notebook 2. It is important to note that the groups were expected to have autonomy to explore the Post-it colors as they saw fit and were not required to associate specific colors with particular categories on the wheels. The markers and board erasers were included to support the visual construction and revision of the current sociotechnical ecosystem represented on the board for each group's topic.

Furthermore, it was established that the tools would not be provided all at once but introduced progressively according to the flow of the practical activities. This strategy was designed to give rhythm to the interactions and prevent confusion regarding the simultaneous use of multiple tools. The facilitators were responsible for distributing the materials, ensuring greater agility and allowing the lead facilitator to focus on guiding the workshop without compromising the time allocated for presentations and discussion facilitation.

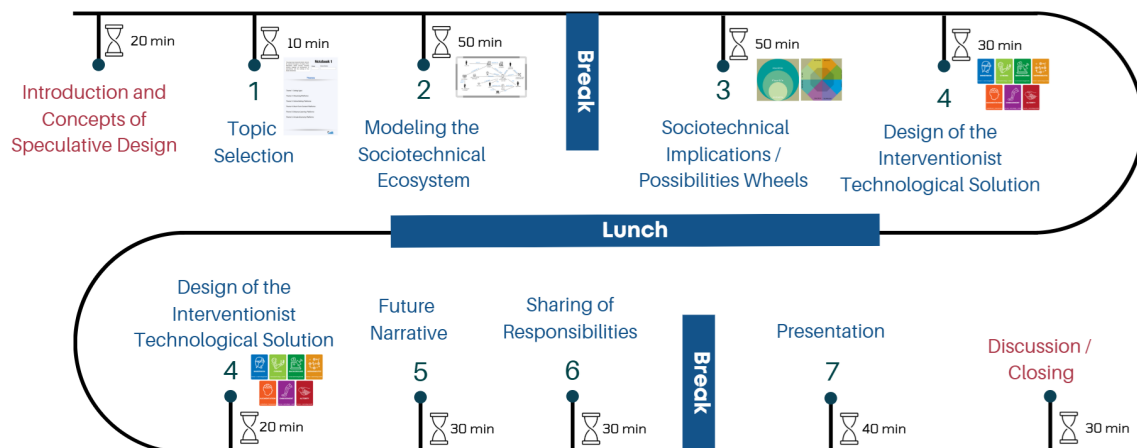
Finally, the lead facilitator prepared a Canva presentation of 72 slides to accompany the workshop, alternating between moments of oral explanation and practical activities. Demonstrations of how to use the tools were embedded in this presentation and instantiated using the theme “Ride-Hailing Services.” The intended strategy was that, for each example shown in Canva illustrating how to apply a particular tool to this theme, participants would apply the same tool to their own topics.

This strategy was considered appropriate because it provided a practical model for tool usage, facilitating participants’ understanding of each step while encouraging creative autonomy in translating the approach to their specific themes. As a result, the need for lengthy theoretical explanations was reduced, making the workshop more dynamic.

6.4.3 Workshop Planning

The workshop was planned to take place over a total of 6 hours, structured into two blocks of three hours each. This organization sought to balance moments of theoretical exposition, collective discussion, and hands-on work with the Speculative Design tools, creating a space for both conceptual and practical experimentation oriented toward the application and exploration of the SEF. The schedule also included strategic buffers in the time allocated to each activity in order to accommodate unforeseen circumstances, such as delays, infrastructure issues, or specific needs that might arise within the groups. Figure 27 presents the sequence of stages planned for the development of the workshop.

Figure 27: Sequence of workshop activities.



Source: Author’s elaboration.

6.4.3.1 Introduction and Concepts of Speculative Design

The introductory stage was planned to present the foundations of Speculative Design and Future-Oriented Design. This segment would outline the core objectives of Speculative Design, emphasizing its differences from traditional design approaches such as Design Thinking, which focuses on solving practical and immediate problems, and Human-Centered Design (HCD), which concentrates exclusively on human expectations and interests.

The plan also included a brief presentation of two representative state-of-the-art studies: the first on MtHD in smart cities (Edwards; Pettersen, 2023), and the second offering an overview of the use of Speculative Design, Critical Design, Futures Design, and Design Fiction in HCI (Zhu *et al.*, 2024).

In addition, key concepts would be introduced, such as sociotechnical ecosystems understood as networks of relations among human and non-human entities, emerging signals, future trends, and their possible long-term implications if they come to be realized. Finally, the objectives of the workshop would be presented.

A clear and inclusive language was planned for this stage, avoiding heavier philosophical terms such as agency, anthropocentrism, or post-anthropocentric values, even though these concepts were implicitly embedded in the tools used throughout the workshop. The 20-minute duration was defined to ensure greater emphasis on practical activities, limiting theoretical exposition to what was essential for guiding the subsequent stages.

6.4.3.2 Stage 1: Topic Selection

Participants were expected to organize themselves into groups of four to five people, with ten minutes allocated to define the theme that would serve as the starting point for speculation throughout the workshop. The theme was required to correspond to a specific sociotechnical ecosystem, such as remote teaching platforms, the *uberization*² of certain activities, or other contexts the groups considered relevant to explore.

To ensure the smooth progression of the activities, four predefined themes were included in Support Notebook 1. These could be used if a group was unable to select its own theme or if the available time proved insufficient for this stage. Considering the maximum limit of 40 participants, up to eight groups could be formed, allowing each of the four themes to be assigned to as many as two groups.

The lead facilitator had previously informed participants that the theme “Ride-Hailing Services” would be used as a demonstrative example throughout the workshop. This theme, however, was not available for group selection, as its function was strictly didactic, serving as a reference for the application of the tools.

²The term *uberization* (*uberização* in Portuguese) is widely used in Brazil to describe labor and service models structured around digital platforms that operate through on-demand, app-mediated, and algorithmically managed work. Although inspired by the company Uber, the expression has become a broader socio-economic concept referring to the flexibilization of labor relations, the expansion of gig work, and the reconfiguration of service provision through platform economies.

6.4.3.3 Stage 2: Modeling the Sociotechnical Ecosystem

For this practical activity, each group was expected to map the sociotechnical ecosystem related to the chosen theme and identify the trends associated with that scenario. The activity was planned to involve group discussions supported by the foundational concepts previously introduced by the lead facilitator, including the objectives of the workshop. It was also planned that an instantiated example of the theme “Ride-Hailing Services” would be shown on a Sociotechnical Board in order to illustrate the process. Based on this example, the lead facilitator would guide the groups to follow three steps: (a) discuss and identify the actants within the scenario, (b) relate these actants to one another by examining how they interact, and (c) identify the trends present in the scenario.

For this stage, a duration of 50 minutes was planned, considering the complex nature of the activity. The extended time was justified by the need to articulate moments of internal debate, in which participants would discuss different perspectives, together with the collective graphical recording on the Sociotechnical Board. This visual representation process required identifying the elements of the ecosystem, reflecting on the connections between humans and non-humans, and analyzing future trends within the scenario. Thus, the 50-minute period was designed to ensure depth in the discussions and quality in the elaboration of the models, preventing the activity from becoming a superficial exercise and fostering the collaborative construction of more consistent scenarios.

6.4.3.4 Stage 3: Sociotechnical and Possibilities Implications

After the 30-minute break, the facilitator-presenter planned to prompt the groups with the following question: **“What if the emerging trends you identified were to materialize in the future? What would the implications be?”**. The proposal was for participants to reflect on potential developments, classifying them as desirable or undesirable and assigning a level of probability to each implication.

To illustrate this stage, an instantiation of the theme “Ride-Hailing Services” would be presented, using Support Notebook 2 together with the Sociotechnical Implications Wheel and the Possibilities Wheel. Each group was then expected to complete Support Notebook 2 by recording: (a) the speculated date; (b) the sequential numbering of each implication (1, 2...n); (c) a brief description; (d) the classification of the implication (positive, negative, or desirable); and (e) its magnitude of impact.

Next, the groups would use the Sociotechnical Implications Wheel to identify the area in which each implication would manifest, with the option to select more than one area. Post-its containing the corresponding number of each implication would be placed on this wheel. Finally, the groups would employ the Possibilities Wheel to assess the likelihood of occurrence of each implication, also using numbered Post-its.

A duration of 30 minutes was planned for this stage, seeking to balance two aspects: ensuring sufficient time for collective reflection and critical analysis of the implications, while avoiding an excessively long activity that might compromise the dynamism of the subsequent speculative stage. The definition of this time frame aimed to maintain a productive rhythm in the workshop, allowing participants to explore scenarios without generating cognitive fatigue.

6.4.3.5 Stage 4: Designing the Interventionist IT Solution

It was planned that the groups would be responsible for designing a technological solution capable of intervening in the previously speculated future. This activity was allocated a total duration of 50 minutes, divided into two parts: 30 minutes at the end of the first block and 20 minutes at the beginning of the second block.

The division into two phases was conceived both to accommodate the available time and to enhance the quality of the activity. Since this stage is central to the process and requires the analysis and integration of the previously completed artifacts, the allocation of 50 minutes was intended to ensure sufficient space for collective reflection, idea formulation, and the elaboration of the solution. The break between the two blocks would also allow participants to resume the activity with renewed perspectives, supporting a more critical and thoughtful creative process.

Once again, it was planned that the presenter-facilitator would use the theme “Ride-Hailing Services” as a demonstrative example. The intention was to show, through this case, how to manipulate the Technological Mediation Cards to extract insights about possible characteristics that an interventionist IT solution could incorporate. With this strategy, the aim was to support participants in thinking about:

- Which features could compose their solutions
- How to mitigate negative implications
- How to amplify positive and desirable implications
- How to design alternatives that are more ethical and socially conscious

To support the activity, a set of guidelines was to be presented to help participants explore the cards:

- Speculation could begin from an initial idea, although this was not required
- Participants were encouraged to avoid relying on preexisting mental models
- The selection of cards should not aim only at fitting them into the participants’ current mental models
- When speculating about a future technology, participants should feel free to imagine solutions that do not yet exist

In addition, the facilitator-presenter was expected to demonstrate examples of how to complete Support Notebook 3, indicating how different types of relations should be documented. The completion of these fields was to be guided by the speculative design characteristics derived from the Technological Mediation Cards. The resulting artifact could represent either a focused or an expanded interpretation of these speculations, describing features of the proposed solution that mitigate negative implications and enhance positive and desirable ones. The facilitator-presenter was expected to emphasize

that it was not necessary to propose a fully developed solution for all mapped implications, but rather to outline plausible and socially responsible pathways for intervention.

6.4.3.6 Stage 5: Future Narrative

It was planned that each group would create two distinct future narratives, written from the point of view of different personas. These narratives should include both human and non-human actors that compose the speculated sociotechnical ecosystem, describing how the projected solution reconfigures their interactions and relations, as well as its impacts.

To support this activity, the facilitator-presenter was expected to provide an example of narratives using the theme “Ride-Hailing Services,” which had been previously reserved for demonstration purposes. This example would incorporate characteristics speculated in the earlier stages of the workshop, such as sociotechnical implications, future possibilities, and the projected IT solution, with the aim of guiding groups regarding the expected level of detail.

Throughout this stage, participants were to be encouraged to develop more engaging narratives, giving names and characteristics to the personas, contextualizing the speculated time period, and describing the scenario in a way that makes the story both plausible and critical. These guidelines are available in Support Notebook 4. The focus of the exercise was not only creative imagination but also reflection on how the proposed technology could minimize negative impacts and enhance positive ones in the speculated future.

This stage was planned to last 30 minutes because it does not require writing long literary texts, but rather dramatizing and narratively prototyping the future scenarios. The allotted time is sufficient to create characters, situations, and conflicts that give substance to the speculation.

6.4.3.7 Stage 6: Sharing Responsibilities

It was planned that the facilitator-presenter would begin this stage by presenting an example of how to complete Support Notebook 5, once again using the theme “Ride-Hailing Services.” In this example, the goal was to illustrate how distinct roles could be distributed among human and non-human actors, emphasizing that effectively addressing an implication requires the involvement and combined strength of multiple actants, reflecting the interdependence inherent to sociotechnical ecosystems.

After the example, groups were expected to complete Support Notebook 5 by assigning specific responsibilities to the actors involved in their own scenarios for the implications they deemed necessary, aiming to mitigate negative implications and enhance positive and desirable ones. Although it was recommended that all previously used tools be considered in this process, it was established that, given the available time of 30 minutes, emphasis should fall primarily on three elements: the future narrative, the projected IT solution and the previously identified implications.

6.4.3.8 Stage 7: Presentation

In the final stage, it was planned that each group would have 5 minutes to present the main results of its Speculative Design journey, totaling 40 minutes of presentations in the case of 8 groups. However, if the number of groups were smaller, the presentation time could be adjusted, freeing additional minutes for other stages.

The content expected to be presented included: the description of the current sociotechnical scenario, the identified trends, the projected desirable and undesirable implications, the proposed interventionist solution, the speculative narrative and the distribution of responsibilities among the involved actants.

6.4.3.9 Discussion and Closing

It was planned that the final stage would consist of a collective discussion with the participants, highlighting the value of speculation as a tool for exploring long-term implications in sociotechnical contexts. The conversation should emphasize the disruptive potential of speculative thinking in the face of uncertainty and the importance of recognizing that actants continuously reconfigure the ecosystems in which they are embedded. Finally, participants would be invited to reflect on the main insights gained throughout the process, reinforcing the ethical and critical dimensions of designing for possible and desirable futures.

6.4.4 Workshop Execution

Developed in two three-hour blocks, the activity combined conceptual exposition, collaborative dynamics, and technological speculation exercises. Throughout the process, adjustments were necessary to adapt the schedule to the real conditions of participation, ensuring that, despite unforeseen challenges, the groups advanced in constructing future scenarios, mapping implications, and proposing interventionist IT solutions, culminating in the creation of narratives and reflection on shared responsibilities.

6.4.4.1 Workshop Participants and Activity Duration

Although the workshop reached the limit of 40 available slots, actual attendance was lower. Since the session took place on the first day of the symposium, it is likely that some registered participants had not yet arrived at the event when the activities began. In total, 20 participants were present throughout the workshop, including university faculty, researchers in HCI, and undergraduate and graduate students.

The total duration of six hours for the Speculative Design workshop proved to be adequate, although some participants considered the time allocated to certain activities relatively short. It is worth noting that the workshop began with a delay of approximately 40 minutes, as part of the registered audience had not yet arrived.

Additionally, some participants reported having misunderstood the schedule, interpreting the workshop as being offered in two separate sessions rather than as a single activity structured into two blocks. This misunderstanding led a few participants to arrive only for the second block, thereby missing the first part of the workshop.

Since only four groups were formed, the time originally planned for certain stages was readjusted to compensate for the initial delays and to align the progression of the activities with the actual participation conditions.

6.4.4.2 Interaction with the Tools

During the workshop, participants demonstrated a high level of engagement in the practical activities, collaborating intensely in the collective construction of the proposed tools. However, the level of attention given to the facilitator-presenter during the theoretical explanations was comparatively lower than the engagement observed in the hands-on stages. This behavior indicates that participants placed greater value on practical experimentation, even though they frequently consulted the facilitators to clarify questions regarding the use of the tools.

Below are some of the most common questions related to the use of the Sociotechnical Board, along with the answers provided by the facilitators:

Sociotechnical Board

- *“Do I need to connect all the actants I identify?”* **Standard Answer:** It is not necessary to connect every possible actant. What matters is verifying whether the identified actant belongs to the sociotechnical ecosystem. If its role is not yet clear, it can remain noted on the board without the need to establish immediate connections.
- *“Should I create something similar to a UML diagram?”* **Standard Answer:** No. The representation of actants on the board is free-form. There is no rigid standard to follow; what is essential is that the diagram fosters discussion and enhances the group’s collective understanding of the modeled sociotechnical ecosystem.
- *“What is the difference between signals, trends, and implications?”* **Standard Answer:** Signals are early indications of change; trends refer to consistent patterns that point toward a possible future direction; and implications correspond to the effects or consequences that may emerge if those trends materialize.
- *“Do I need to make visually appealing drawings?”* **Standard Answer:** There is no need for aesthetically refined drawings. What matters is that the board fulfills its practical purpose, helping expand the group’s understanding of the sociotechnical ecosystem and supporting collective discussion.

The following section presents the questions most frequently raised by participants regarding the use of the Sociotechnical Implications Wheel, together with the standardized answers provided by the facilitators:

Sociotechnical Implications Wheel

- *“Is it necessary to use a different Post-it color for each type of implication?”* **Standard Answer:** There is no fixed rule. The way Post-its are used is up to the group. You may organize implications (positive, negative, and desirable) by color if you find it helpful, or you may choose another organizational criterion.

- “*Can an implication affect more than one area of life? For example, politics and religion?*” **Standard Answer:** Yes. Many implications cut across multiple areas of life. In such cases, you may indicate all relevant areas or highlight only the area where the implication seems most significant.
- “*What if I cannot find an appropriate area on the wheel, or if the implication belongs to an area that is not represented?*” **Standard Answer:** In this situation, you may place the numbered Post-it outside the wheel and create a new Post-it specifying the area that best represents the implication.
- “*What is the meaning of the darker and lighter areas on the Sociotechnical Implications Wheel?*” **Standard Answer:** The darker region represents implications already underway, whereas the lighter region indicates implications projected to occur in the speculated future.

The following section presents the questions most frequently raised by participants regarding the use of the Possibilities Wheel, along with the standardized answers provided by the facilitators:

Possibilities Wheel

- “*What is the difference between possible, plausible, and probable?*” **Standard Answer:** The term **possible** refers to something that may happen, even if the probability is low. The term **plausible** refers to a more consistent possibility, meaning something that makes sense within a given context; every plausible implication is also possible, since it is contained within that broader set. The term **probable** indicates the highest degree of likelihood, that is, what has the greatest chance of occurring. Therefore, if something is probable, it is also plausible and, consequently, possible.
- “*What if the implication is impossible to occur?*” **Standard Answer:** If an implication is considered impossible, it should not have been mapped in the first place. The very act of registering it indicates that it is perceived as having at least some chance of occurring, however small, which places it at minimum within the category of possible.

The following section presents the most frequently asked questions regarding the use of the Technological Mediation Cards, along with the standardized answers provided by the facilitators:

Technological Mediation Cards

- “*Where does the Mediation Type come from?*” **Standard Answer:** The mediation types derive from the Theory of Technological Mediation proposed by Verbeek (2005a), which describes seven ways in which technology mediates the relationship between humans and the world. However, it is not necessary to delve into this theoretical framework during the workshop. What matters most is the practical exploration of the cards. If participants wish to learn more about the theory, reference material can be shared after the event.

- “*What if I use a card of one mediation type and end up thinking of a technological feature that does not correspond to that card?*” **Standard Answer:** There is no right or wrong answer. Technological mediations are not rigid categories but fluid conceptual orientations. What is essential is that the cards serve as instruments to support speculation and guide the design goals defined by the group.
- “*Is there a correct way to explore these cards?*” **Standard Answer:** No. Each group is free to decide how to explore the cards, adapting them to their creative process.
- “*Do I need to provide examples similar to the ones shown on the card?*” **Standard Answer:** No. The examples on the cards are merely illustrative and serve only as support for understanding the logic of each mediation type.
- “*Does the final feature of the IT solution need to align with the card we explored?*” **Standard Answer:** No. The cards are sources of inspiration, not mandatory rules. The final solution may or may not directly reflect the exploration of a specific card.

6.4.4.3 Adjustments Made During the Workshop

Due to the initial delay of approximately 40 minutes and the arrival of new participants throughout the session, it was necessary to implement several adjustments to the planned sequence of activities:

- The time allocated for introducing the core concepts of Speculative Design was reduced from 20 to 10 minutes, prioritizing the practical activities.
- Groups were no longer able to propose their own themes; instead, themes were predefined and offered by the facilitator-presenter through Support Notebook 1.
- Groups were initially formed with only 2 or 3 participants, and as new participants arrived, facilitators redistributed them in order to balance group composition.
- The support facilitators had to take on a more active role, explaining to late-arriving participants which activities had already been completed and how they had been conducted, helping them quickly integrate into the workflow of the workshop.
- At the beginning of the second block, the facilitator-presenter provided a brief overview of the activities completed in the first block to ensure alignment among all participants.
- The activity involving the creation of future narratives was simplified: instead of developing two narratives, each group produced only one, and the time allocated was reduced from 30 to 20 minutes.

6.4.4.4 Produced Material

During the workshop, four groups were formed, each composed of 4 to 6 participants, who selected the following themes for investigation: Group 1 explored “Dating Websites and Apps”; Groups 2 and 3 worked on “Streaming Platforms”; and Group 4 focused on

“Online Betting Platforms (BETS).” Each group produced a set of artifacts throughout the workshop, documenting the speculative and design processes they developed. The materials produced were:

- **Completed Sociotechnical Board:** constructed using markers of varying colors and thicknesses, accompanied by large Post-its containing the future trends identified for the analyzed scenario.
- **Sociotechnical Implications Wheel:** completed with numbered Post-its placed in the areas corresponding to the domains of life in which each implication was perceived.
- **Possibilities Wheel:** completed with numbered Post-its indicating the degree of possibility for each previously mapped implication.
- **Support Notebook 2:** containing a detailed list of implications, including numbering, description, magnitude (high, medium, or low), classification (positive, negative, or desirable), and the speculated date of occurrence.
- **Support Notebook 3:** documenting the types of technological mediation explored, the design characteristics of the proposed technical solution, and descriptions of how the solution aimed to maximize positive and desirable implications while mitigating negative ones.
- **Support Notebook 4:** containing the development of the projected future narrative, including characters, settings, and interactions between human and non-human entities.
- **Support Notebook 5:** detailing the distribution of responsibilities among the different actants involved in the proposed solution, with the aim of mitigating negative effects and strengthening positive and desirable ones.

6.5 Data Collection

Photographs were taken of the Sociotechnical Boards, the Sociotechnical Implications Wheels, and the Possibilities Wheels produced by each group. In addition, all completed Support Notebooks were fully transcribed. The entire dataset was subsequently systematized using the Framework Method (Klingberg *et al.*, 2024; Gale *et al.*, 2013), which guided the organization, tabulation, and structuring of the data for the content analysis stage. This method was selected because it provides a systematic and flexible approach for handling qualitative data, suitable for multidisciplinary teams and large volumes of textual information.

Data tabulation and organization were carried out in Microsoft Excel, allowing the integration of graphical representations and Support Notebook entries into a single structured dataset. This stage facilitated a non-redundant compilation of the material and enabled cross-group comparisons. The complete tabulated dataset is available in the Zenodo repository³.

³Zenodo repository link for the Tabulated Data: <https://doi.org/10.5281/zenodo.15134870>

In addition, at the end of the workshop an online questionnaire was administered and made available to participants for one month so they could record their perceptions of the experience. The instrument was developed based on the ARCS model (Attention, Relevance, Confidence, and Satisfaction), a motivational design framework that identifies core factors influencing learner engagement and persistence. This model guides the planning of learning experiences that are capable of capturing participants' attention, establishing relevance, fostering confidence in their abilities, and ensuring satisfaction with the educational process (Li; Keller, 2018; Keller, 1987).

The questions were organized into thematic axes corresponding to the components of the ARCS model, with two questions for each axis. The responses were incorporated into the analytical corpus for triangulation with the other qualitative data, as detailed in Appendix E.

6.6 Data Analysis

The data analysis in this study combined complementary qualitative procedures to understand not only the materials produced during the speculative workshops but also the emergent movements that traversed and exceeded the activities themselves, including processes, interactions, decisions, reciprocal influences, and effects that unfolded beyond the immediate boundaries of the workshops.

6.6.1 Content Analysis

Content Analysis (Sousa; Santos, 2020) enabled a systematic interpretation of the data collected in the participatory workshops, including transcripts, spreadsheets, and participant records, with particular emphasis on cross-comparison as the central analytical technique. The analysis also incorporated the responses from the online questionnaire to triangulate declared perceptions with discourses and practices, thereby strengthening interpretive robustness. The analytical process was conducted in four main phases:

1. **Pre-analysis:** conducted in the preceding stage, this phase consisted of organizing and preparing the collected material and defining the guidelines that would orient the analytical approach.
2. **Material exploration:** the corpus was examined exhaustively, identifying units of meaning and proceeding with the coding process, that is, the categorization of textual fragments based on emerging themes and on the theoretical concepts associated with the SEF's post-anthropocentric principles.
3. **Cross-comparison and interpretation of codes:** the central stage of the analysis, during which the codes were systematically compared and contrasted in order to identify similarities, differences, and interrelations among categories, statements, and units of meaning. Cross-comparison made it possible to verify hypotheses formulated in the initial phase and to understand how meanings were distributed across groups and workshop contexts. This practice ensured precision, coherence,

and interpretive depth, revealing patterns and latent meanings present in the accounts.

4. **Treatment of results:** the phase of inference and final interpretation, which consolidated the patterns and tensions identified throughout the cross-comparison process. This stage made it possible to highlight convergences, divergences, and tensions between the groups' perceptions and the post-anthropocentric principles that underpin the SEF.

The evaluation criteria used derive directly from the principles formulated, establishing an almost literal correspondence between them. These criteria are detailed in Table 13.

Table 13: Evaluation Criteria Based on Post-Anthropocentric Principles.

P#	Evaluation Criterion
P1	Whether the groups identified and represented both human and non-human actors, reflecting on their interactions.
P2	Whether participants considered how artifacts influence human perception, actions, and decision-making.
P3	Whether the interdependencies among actants and the emergent phenomena arising from these relations were mapped.
P4	Whether speculation was used to explore uncertain, non-linear futures with multiple possible outcomes.
P5	Whether the groups explored and validated the existence of hybrid actors as legitimate participants in the network.
P6	Whether participants reflected on the ethical implications and the distribution of responsibilities emerging from enactment processes.

Source: Author's elaboration.

In addition, counts of relevant information were conducted to support the analysis of the post-anthropocentric principles. As an example, Figure 28 presents the results of the count performed using the Sociotechnical Board from Group 3.

In this representation, the red ellipses correspond to non-human actants and the red lines indicate forms of non-human agency. The green ellipses represent human actants and the green lines represent human agencies. The Post-it notes positioned at the bottom of the figure record the trends mapped by the groups.

A quantitative survey was also conducted of the future implications identified for each domain of life, based on the count of Post-it notes inserted into the Sociotechnical Implications Wheel.

Although it was not possible to determine in detail which Technological Mediation Cards were used by each group, the analysis of Notebook 3 made it possible to identify the types of mediation explored.

Finally, an analysis was carried out of human and non-human actants, including the count of their distribution in the responsibility matrix recorded in Notebook 5. All of these data were synthesized into tables, which are presented in Section 8.

6.6.2 Diffractive Analysis

To broaden the interpretation of the empirical material, diffractive analysis (Barad, 2007) was adopted as a complementary approach. Considering that the set of possible

Legend

- Human (Green circle)
- Human Agency (Green line)
- Non-Human (Red circle)
- Non-Human Agency (Red line)

Trends

- Use of AI
- New screen limitations
- Only unique content
- Increase in piracy
- Streaming bundles
- Increase in shows

intra-actions is virtually infinite, it became necessary to establish agential cuts, that is, delimitations that define what becomes relevant within the context of this investigation. The choice of certain voices, materials, and records, as well as the conscious exclusion of others, does not constitute a methodological limitation; it is an intentional analytical gesture, aligned with the understanding that every act of knowing involves drawing boundaries that produce differences.

From this perspective, the multiple elements present throughout the research—such as the advisor’s interventions, reviewers’ reports, the tools employed, the SEF, and the speculative results themselves—are recognized as apparatuses that configure the conditions of possibility for the phenomenon under investigation. These elements do not operate in isolation nor precede the process; they co-emerge continuously within the material-discursive entanglement that constitutes both the conduct of the workshop and the very writing of this dissertation.

102

6.7 Final Considerations of the Chapter

This chapter presented the methodological architecture that supports the empirical dimension of this dissertation, showing that the methodological choices were not isolated technical decisions but constitutive components of the very process of “designing the dissertation.” By advocating Entanglement Theories as a foundation for designing IS, it became necessary to acknowledge that the research itself should also be conducted according to the same principles that guide the proposed framework. The adoption of the Entanglement Paradigm and diffractive analysis therefore expresses a methodological stance consistent with the refusal of modern dichotomies, especially the bifurcation between nature and culture, and prevents the dissertation from falling into contradiction with its own theoretical claims.

This chapter also presented the execution of the workshop, described in its material and relational dimensions, demonstrating how the SEF operates in practice by allowing participants, tools, and artifacts to configure a hybrid and intrinsically relational investigative phenomenon. Likewise, the data collection and analysis procedures adopted, combining content analysis and diffractive analysis, were chosen to address the multiplicity of voices, materialities, and mediations present in the process. These methods made it possible to interpret both discursive patterns and the performativity of the encounters, respecting the complexity of sociotechnical ecosystems and reaffirming the epistemological commitment of this dissertation to non-reductionist approaches.

7. Future Scenarios and Technological Solutions Designed in the Workshop

This chapter presents the future scenarios and technological solutions developed throughout the workshop. These materials are organized into four thematic sets: Dating Applications, Streaming Platforms (Groups 2 and 3), and Betting Platforms. For each set, the chapter outlines the identified current scenario, the projected trends and their implications, the technological solution conceived by the participants, the alignment between the solution and the projected implications, and the distribution of responsibilities between human and non-human actants in the envisioned future ecosystem.

7.1 Contextualization

To facilitate the understanding of the material generated throughout the workshop, the decision was made not to present the images of the Sociotechnical Boards, the Sociotechnical Implications Wheels, and the Possibilities Wheels directly. These visual records emerged from intensive internal group discussions and, when viewed in isolation, would hinder analytical interpretation. As an alternative, a mind map was created to synthesize the key elements: the theme and trends extracted from the Sociotechnical Boards; the implications, their magnitude, and their classification recorded in Support Notebook 2; the life domains corresponding to the implications identified in the Implications Wheels; and the probability levels indicated in the Possibilities Wheels.

In a similar manner, analytical tables were developed to consolidate, in a single format, the types of mediation and the reflections produced by the groups through the Technological Mediation Cards. This systematization made it possible to clarify how the proposed solutions sought to amplify positive implications and mitigate negative ones. Information from Support Notebook 5, related to the distribution of responsibilities among the actants in the ecosystem, was also organized.

Furthermore, the relationship between the types of mediation explored and the characteristics of the interventionist IT solutions was made explicit, enabling an understanding of how the speculative exercises supported the design of the proposed interventions.

7.2 Dating Sites and Platforms (Group 1)

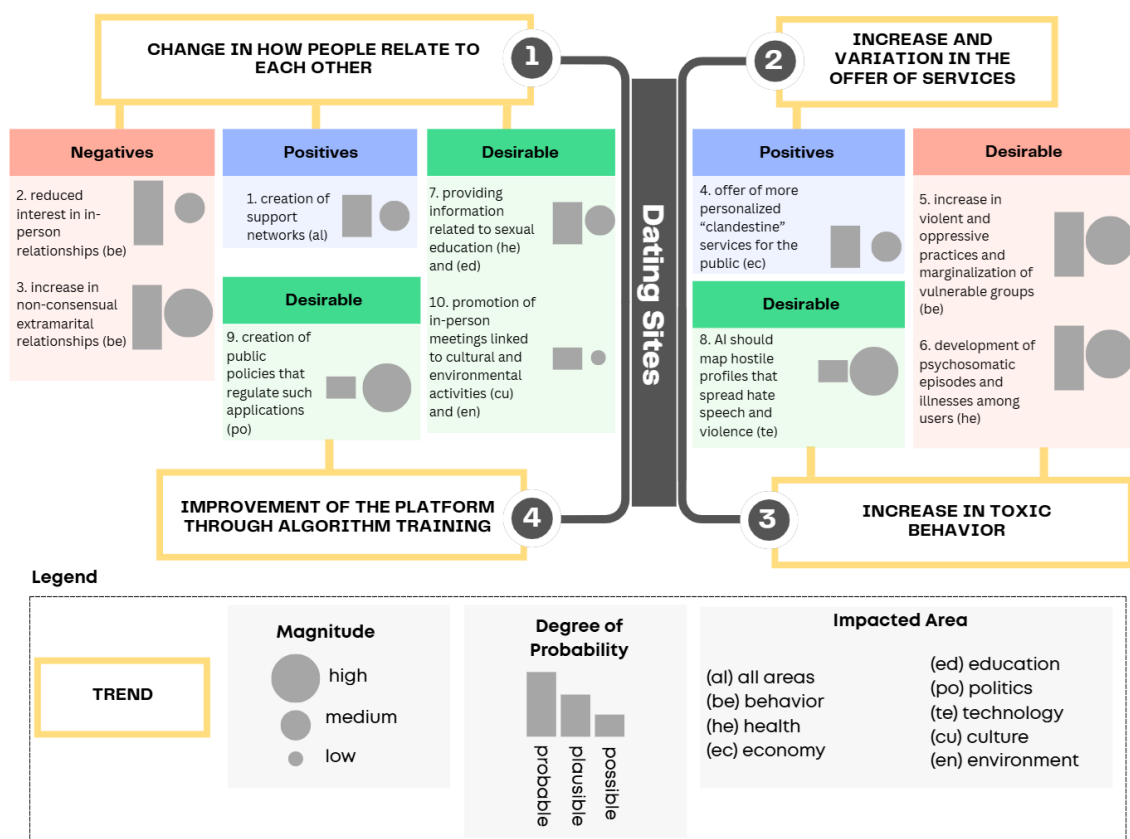
Group 1 selected dating applications and online relationship platforms as their theme, investigating the possible futures of this type of service.

7.2.1 Current Scenario and Future Implications

Based on the mapping of the current sociotechnical ecosystem, conducted using the Sociotechnical Board, the group identified four main trends that, if consolidated by 2030, may generate significant implications across different dimensions of social life. To analyze these projections, the Sociotechnical Implications Wheel and the Possibilities Wheel were used, allowing the classification of implications according to type (positive, negative, or desirable), impact magnitude (low, medium, or high), and probability of occurrence (possible, plausible, or probable). All information was systematized in Support Notebook 2.

To improve the integrated visualization of the results, a mind map was created, shown in Figure 29, consolidating the trends identified by the group and their corresponding implications.

Figure 29: Speculative Scenario: Dating Applications in 2030 (Group 1).



Source: Author's elaboration.

The data generated by Group 1 present a speculative cartography of the possible futures of dating sites and platforms, identifying four major trends that may profoundly reconfigure modes of affective, social, and technological interaction by the year 2030. The first of these trends concerns changes in how people relate to one another, indicating a significant shift from in-person relationships toward experiences mediated by digital platforms. This transition raises both concerns and opportunities. On the one hand, negative implications were identified, such as a reduced interest in forming in-person

bonds and a potential increase in non-consensual extramarital relationships, both exerting strong influence on behavioral dimensions. On the other hand, positive and desirable implications were envisioned, including the emergence of support networks that cut across multiple areas of life, the promotion of sexual education through these platforms, and even the encouragement of in-person meetings oriented toward cultural and environmental activities.

The second trend analyzed concerns the expansion and diversification of services offered by these platforms. The possibility of highly personalized services, including those considered “clandestine,” emerged as a positively perceived implication from an economic standpoint. However, the meaning of “clandestine” was not entirely clear. It may refer to hidden or lower-cost services enabled through specific configurations or unconventional interactions, or to services operating independently and outside the reach of major platforms, often providing alternative solutions not officially recognized. For the group, these services seem to represent a way of meeting particular needs, often associated with behaviors or demands that fall outside regulated scopes.

The third trend, identified as the increase in toxic behavior, appears as a direct consequence of intensified online interactions and algorithmic architectures that frequently favor polarization and conflict. The group warned about the potential escalation of violence and oppression targeting vulnerable groups, as well as the emergence of psychosomatic illnesses linked to intensive platform use, directly affecting users’ mental health. In response to these threats, one of the desirable proposals presented was the use of AI to identify and neutralize hostile profiles, counteracting hate speech and violence and assigning technology an active role in containing harmful behaviors.

Finally, the fourth trend concerns the continuous enhancement of platforms through the training of increasingly sophisticated algorithms. This dimension intersects with and reinforces the other trends, functioning as a structuring axis of the speculative transformations. The ability of artificial intelligence to respond effectively to abusive behaviors, personalize services, and broaden access to relevant information depends directly on this ongoing process of technical refinement. In this context, the group highlighted the need for public policies aimed at regulating and guiding the use of these technologies, revealing a concern with the ethical and institutional mediation of this sociotechnical phenomenon.

7.2.2 Speculation of the Technological Solution

In the next stage, participants conducted a design exploration using the Technological Mediation Cards, which are based on the Technological Mediation Theory proposed by Verbeek (2005b). Each type of mediation served as a lens for critical reflection on the ways technology can shape user experiences and influence social practices. During this phase, the cards were explored and the resulting reflections were recorded under the corresponding mediation type in Support Notebook 3, as presented in Table 14.

It is important to emphasize that the exploration of the cards and the completion of the mediation types do not necessarily determine the elements that will appear in the final solution. However, it was from this exploratory process that the group designed a

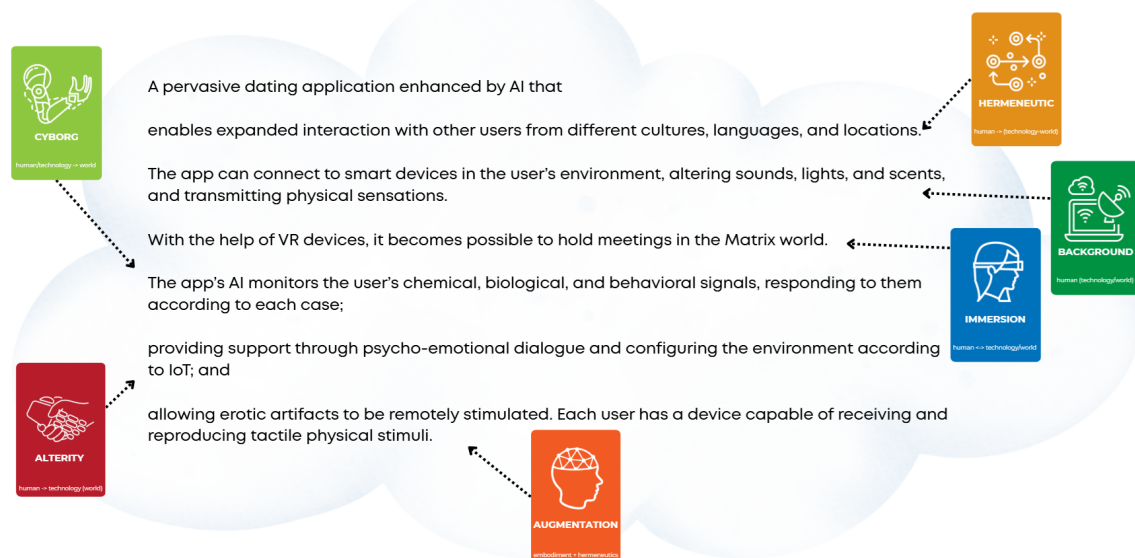
Table 14: Design Reflections Based on the Types of Technological Mediation.

Type of Mediation	Design Reflections
Embodiment	N/A
Alterity	The app should include a psycho-emotional support feature, assisting users in dealing with situations arising during interactions, such as identifying toxic, manipulative, oppressive, or sexist discourses.
Hermeneutic	The app could translate interactions in real time, including support for other spoken languages and sign languages.
Background	The app may connect through IoT devices to adjust lights, sounds, or scents according to the flow of the conversation.
Cyborg	The app, through a chip, IoT device, or smartwatch, could detect and inform users about their physiological reactions when interacting with others and warn them of potential consequences.
Immersion	Through VR glasses, users could interact with one another in a “metaverse” environment co-defined by both parties.
Augmentation	The app could activate remote erotic devices. Each user would possess an artifact capable of receiving and reproducing tactile physical stimuli.

Source: Author’s elaboration.

technological solution projected for the year 2030, presented in Figure 30.

Figure 30: Proposed Solution: Dating Applications in 2030 (Group 1).



Source: Author’s elaboration.

The result was an ambitious and provocative proposal: an application that not only connects users but also actively co-constructs the meeting space, functioning as a hybrid environment that integrates digital and physical dimensions to promote safer, more responsive, and more inclusive experiences. For example, the **alterity** mediation inspired the creation of a feature in the application capable of offering emotional support in situations of toxic interaction, such as manipulative or oppressive statements. The **hermeneutic** mediation motivated the incorporation of real-time translation for interactions between users who speak different languages. The **immersion** mediation supported the idea of personalized encounters in virtual reality environments. Finally, the **cyborg** mediation led to the proposal of wearable devices that, by detecting biometric and emotional signals, would allow the application to respond proactively to situations of risk. The cards function as heuristic devices aimed at expanding the field of

possibilities and stimulating critical imagination, rather than as mandatory prescriptions for the design of the artifact.

7.2.3 Alignment with the Main Objectives

Next, each implication of the futuristic scenario was associated with specific features of the proposed solution, as presented in Table 15. This mapping aligns with the central objective of the workshop, which is to design a technological solution capable of enhancing positive and desirable implications while seeking to mitigate or neutralize the negative implications identified during the speculation process.

Table 15: Proposed solutions for the identified implications.

Impl. Code	Solution for the Implication
1	The app may suggest contacts when it identifies that the user is in need of support and assistance.
2	VR immersion makes the interaction less impersonal.
3	N/A
4	AI, VR, and IoT technologies enhance the display of the service portfolio.
5	The AI detects behaviors and speech, penalizing the user.
6	The AI's emotional support would provide care and activate the support network and devices.
7	The AI would demonstrate and explain details regarding sexual health through VR.
8	The AI detects behaviors and speech, penalizing the user.
9	The AI would analyze the data (including user feedback), cross-reference it with human rights standards and federal laws, and suggest bill proposals.
10	VR and IoT can offer a free sample experience.

Source: Author's elaboration.

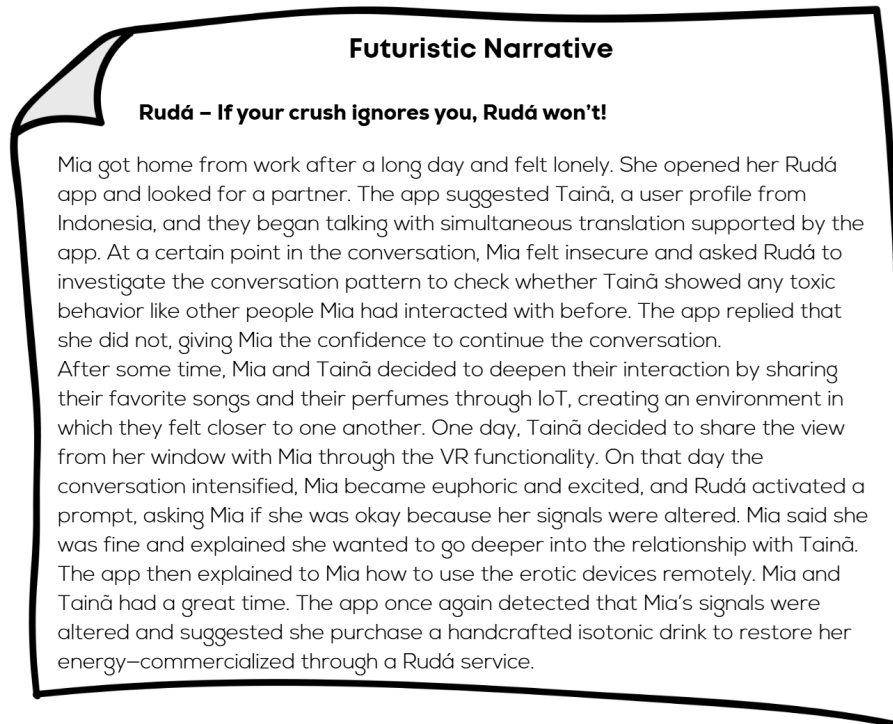
For example, to address the need for support networks (Implication 1), the application could suggest trusted contacts when signs of distress are detected. To avoid impersonal communication (Implication 2), immersive virtual reality would enhance the depth and richness of interactions. Moreover, technologies such as Artificial Intelligence (AI), Virtual Reality (VR), and the Internet of Things (IoT) are regarded as catalysts for diversifying services, since they strengthen the presentation and adaptation of the service portfolio, enabling more immersive, dynamic, and personalized experiences (Implication 4). The technology would also be capable of detecting hate speech and abusive behaviors (Implication 5), penalizing users who violate the guidelines and activating support systems when necessary, such as in episodes of psychosomatic illnesses triggered during the use of the platform (Implication 6). To contribute to public policy (Implication 9), the system could analyze user feedback and existing legislation, suggesting draft policies aligned with users' rights. Finally, to encourage in-person encounters with cultural and educational purposes (Implication 10), VR and IoT resources could be employed to offer demonstrative experiences or free samples.

7.2.4 Futuristic Narrative and Shared Responsibilities

After designing the technological solution, Group 1 developed, based on the guidelines of Notebook 4, a futuristic narrative that contextualizes its use within the speculated scenario. This narrative, presented in Figure 31, introduces the Rudá platform and creatively illustrates its functioning in the 2030 context. In addition to describing functionalities, the text stages interactions among humans, technologies, and environments, revealing the projected sociotechnical dynamics. This performative

dimension brings the designer closer to the imagined experiences and highlights the tensions, possibilities, and innovations that emerge from the proposal.

Figure 31: Futuristic narrative (Group 1).



Source: Author's elaboration.

Next, the group revisited the results obtained with the different tools in order to analyze them in an integrated manner, reflecting on how responsibilities would be distributed among the various actants involved in each speculated implication.

The Sociotechnical Board was used to identify which actants remain in the future ecosystem reconfigured by the introduction of the Rudá platform, which ones cease to operate, and which new actants become part of it. The Sociotechnical Implications Wheel and the Possibilities Wheel, articulated with the Notebooks, made it possible to map the most urgent actions, while the types of technological mediation provided support for speculation, alignment with the workshop objectives, and innovation in the design of the solution. Finally, the futuristic narrative reinforces this integration by giving performative materiality to the proposal, staging how the technology operates within the speculated environment and making its sociotechnical dynamics tangible.

The association between implications and responsibilities mapped by Group 1 in Notebook 5 is presented in Table 16.

A distribution of responsibilities between human and non-human actants was observed across the identified implications. Users were expected to follow the guidelines of the Rudá platform and use the information responsibly. The application was responsible for protecting user data and privacy, while the developer company had the obligation to maintain the confidentiality of this information. The government would assume the role of creating and enforcing public policies, and the AI system would act in

Table 16: Responsibilities assigned to different actants, categorized by implication codes (Group 1).

Imp. Code	Responsibilities of the Actants
1	User: Behave in accordance with the Rudá platform guidelines AI: Detect user needs and connect them to appropriate support networks
2	Feedback System: Monitor and inform the system based on user-provided data Application: Prevent third parties from saving or capturing user interactions Developer Company: Refrain from sharing user data with third parties
4	User: Report advertisements that violate the platform's policies Vendors: Follow marketplace regulations AI: Routinely check for fraud and irregularities
5	User: Comply with platform rules AI: Monitor behaviors and make decisions
6	AI: Identify critical episodes and take preventive actions Mental Health Professionals (MHP): Analyze cases to improve AI performance
7	AI: Provide reliable information User: Use the information responsibly
8	AI: Flag, report, and remove users who promote hate speech Government: Apply penalties and sanctions
9	Government: Legislate on the matter AI: Suggest legislative proposals User: Promote democratic engagement

Source: Author's elaboration.

detecting risks, proposing actions, supporting ethical practices, and collaborating in the formulation of regulatory frameworks. In this way, the proposed solution envisions a new mode of technologically mediated interaction sustained by a distributed and ethical network of shared responsibilities.

7.3 Streaming Platforms (Group 2)

Group 2 explored the scenario of Streaming Platforms projected for 2030 but did not complete all the workshop stages. The stage that aligned the features of the solution with the objectives, which consisted of maximizing positive implications and minimizing negative ones, was not carried out. As a result, the proposal became less connected to the commitments established for the activity, although it remains equally relevant for this research.

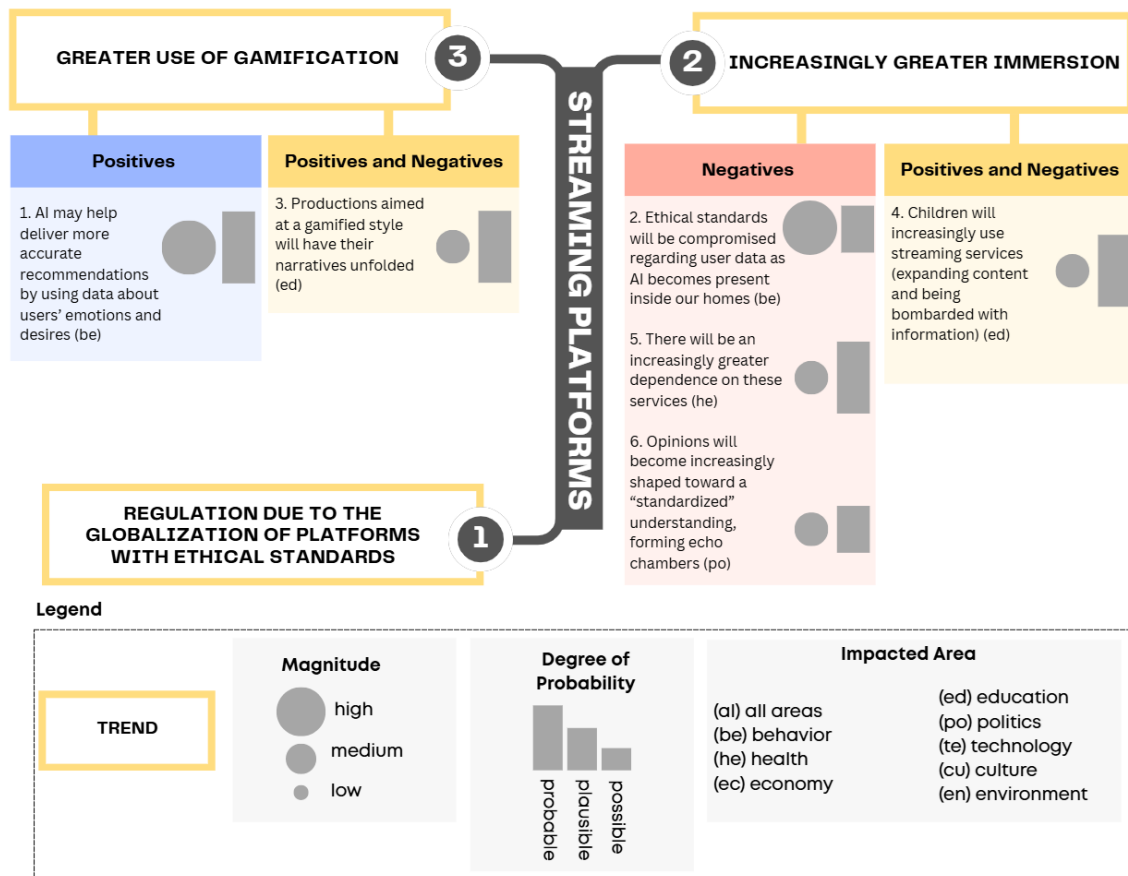
7.3.1 Current Scenario and Future Implications

The mind map presented in Figure 32 represents the speculative scenario for streaming platforms developed by the group through the application of the Sociotechnical Board, the Sociotechnical Implications Wheel, and the Possibilities Wheel.

The speculative scenario identifies three main trends that, if realized, may significantly impact streaming platforms: regulation due to the global expansion of platforms with ethical standards, increasing levels of immersion, and the growing use of gamification.

Global regulation through the establishment of ethical standards involves the advancement of international policies aimed at data protection and the creation of shared guidelines for platform operations. However, no implications derived from the future

Figure 32: Speculative scenario: Streaming Platforms in 2030 (Group 2).



Source: Author's elaboration.

projection of this trend were identified. The trend of increasing immersion is associated with the intensification of consumption experiences, with greater sensory engagement and interactivity. The growing use of gamification refers to the incorporation of playful elements and game mechanics to attract and retain users.

These trends generate positive, negative, and ambiguous implications. Among the positive ones, the potential of artificial intelligence to offer more accurate recommendations stands out, based on the analysis of users' emotions and desires, thereby enhancing the personalization of the experience. Among the negative implications, ethical concerns emerge regarding the intrusive access of AI to personal data within the domestic environment, the risk of increasing dependence on streaming services, and the shaping of opinions toward homogeneous patterns, forming information bubbles.

The positive and negative implications include the possibility that productions with a gamified style may intensify narrative interaction while also simplifying or impoverishing the content, and the increase in streaming consumption among children, which may expand access to educational content while also exposing them to information overload.

7.3.2 Speculation of the Technological Solution

Table 17 presents the records of Group 2's reflections during the exploration of the Technological Mediation Cards, which were used to intervene in the speculated future scenario.

Table 17: Reflections on Design Aspects Based on Mediation Types.

Mediation Type	Reflections on Design Aspects
Embodiment	N/A
Alterity	The VR device may project the current space, immersing the user through all senses. In this scenario, a user-controlled (or not) "film" could be displayed.
Hermeneutic	Every series or film would be automatically localized, in terms of setting, to the user's city.
Background	N/A
Cyborg	The streaming service would know what to display in order to alter the user's emotions according to their needs, such as a series to relax a stressed user or a film capable of making them cry.
Immersion	N/A
Augmentation	The device's sound, brightness, and color system may be controlled by the mind, allowing the user to adjust these resources even unconsciously. For example, a user sensitive to light could automatically reduce brightness, and a color-blind user would have colors adapted to their needs.

Source: Author's elaboration.

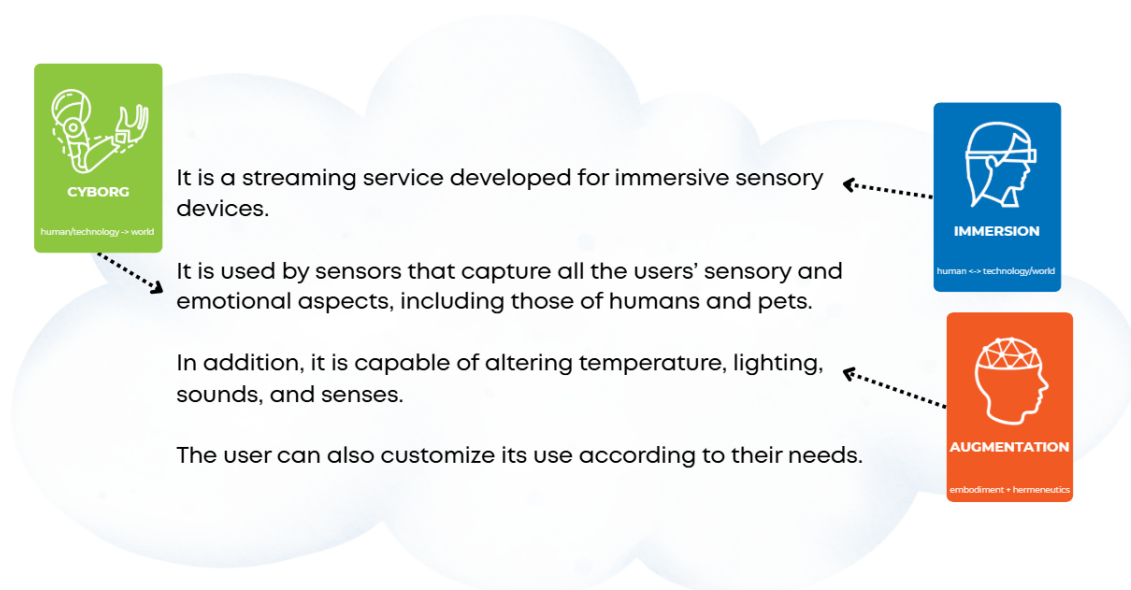
The group proposed several ways to reconfigure the user experience. The mediation of **alterity** inspired the design of virtual reality devices capable of projecting immersive and personalized environments, potentially controlled by the users themselves. The **hermeneutic** mediation supported the proposal of automatic content localization, adapting series and films to the cultural context of specific regions. The **cyborg** mediation led to the idea of an emotionally responsive streaming platform capable of adjusting experiences based on users' emotional states. Finally, the mediation of **augmentation** supported the concept of adaptive devices that modulate color, sound, and brightness according to users' cognitive or physical needs, such as light sensitivity or color blindness. Despite the diversity of ideas, the final solution, illustrated in Figure 33, incorporated only part of these possibilities.

The projected streaming service uses sensors capable of capturing sensory and emotional aspects of users, including interactions with pets. These data allow the system to adapt both the content and the environment, controlling variables such as temperature, lighting, sounds, and other sensory stimuli. In addition, the system offers a high degree of personalization, enabling each user to configure the experience according to their specific preferences and needs.

7.3.3 Futuristic Narrative and Shared Responsibilities

Figure 34 presents the futuristic narrative developed by Group 2, which describes a sociotechnical ecosystem in which the agency of non-human actants plays a central role in Galileu's experience. The Istar device acts as an active mediator, interpreting emotional and sensory signals to adjust colors, sounds, scents, and interactions responsively, while Mimo the cat, by seeking affection, directly interferes with the course of the immersion.

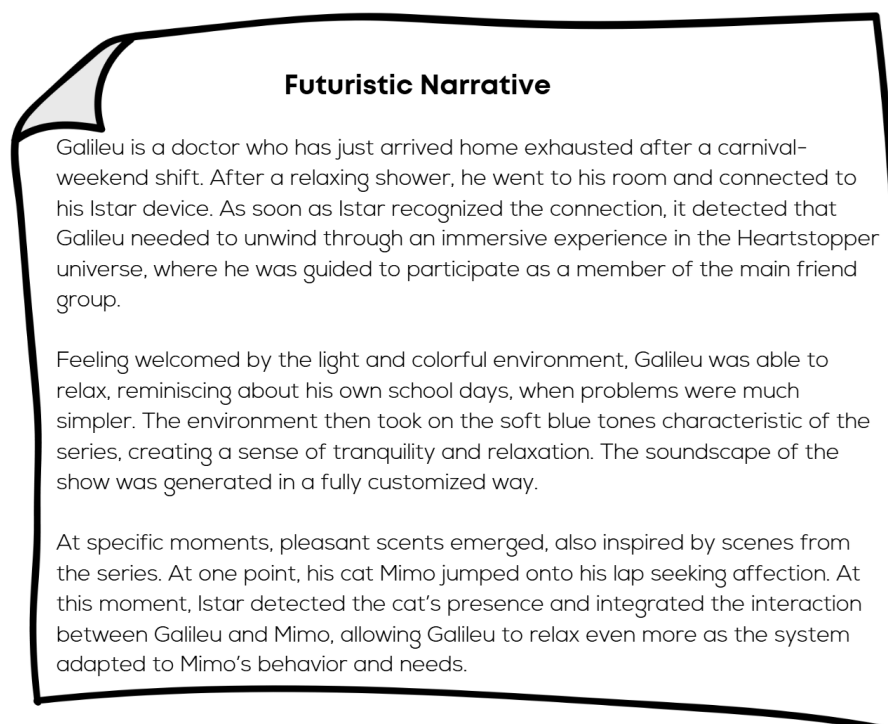
Figure 33: Proposed Solution: Streaming Platforms in 2030 (Group 2).



Source: Author's elaboration.

Technology and the animal not only react but actively shape the experience, forming an entanglement in which Galileu, Istar, and Mimo co-create moments of well-being.

Figure 34: Futuristic narrative (Group 2).



Source: Author's elaboration.

The group also examined the sharing of responsibilities among the various actants in the imagined sociotechnical network, presented in Table 18.

Table 18: Responsibilities assigned to different actants, categorized by implication codes (Group 2).

Imp. Code	Responsibilities of the Actants
1	AI: Provide more accurate recommendations by adapting them to the user's desires User: Choose the operating mode of the device, deciding whether or not to relinquish control as a "character"
2	AI Developer Company: Use the collected data responsibly Regulatory Agencies: Develop standards for new types of collected data (brain waves, emotions, etc.)
4	Child's Parents: Regulate and monitor the content consumed by the child
5	Device: Provide diverse content and implement mechanisms to prevent (or mitigate) dependency
6	User: Seek content outside their comfort zone Recommendation System: Avoid centering content solely on user interests by diversifying the type of content presented

Source: Author's elaboration.

AI systems would be responsible for generating more precise recommendations, while users would decide the level of control they wish to maintain over their experience. Developer companies would assume ethical responsibility for the management of sensitive data, and regulatory agencies would define new standards for the collection and use of such information. In addition, parents, devices, and recommendation systems were identified as key actants in mitigating dependency, diversifying access to content, and expanding users' informational horizons.

7.4 Streaming Platforms (Group 3)

Group 3 also explored the domain of Streaming Platforms and, unlike Group 2, completed all stages of the process, presenting significant variations in the speculated content.

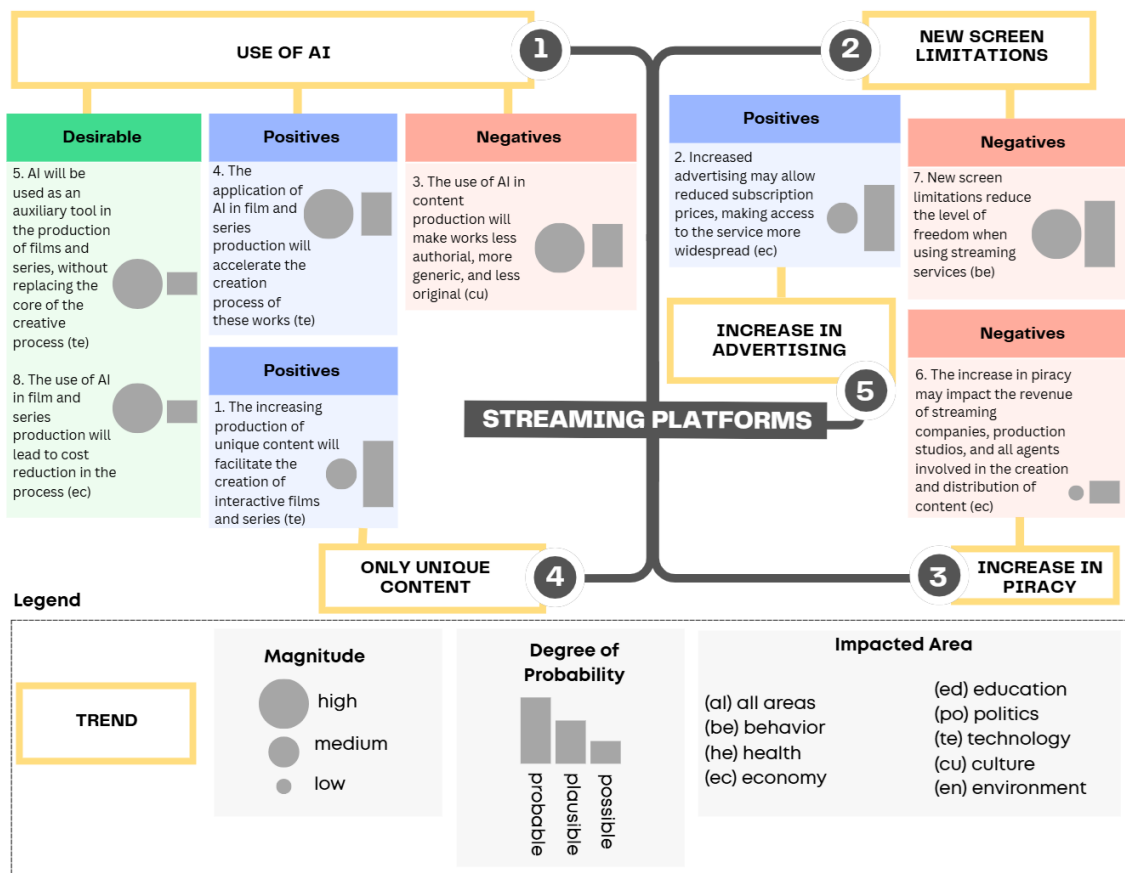
7.4.1 Current Scenario and Future Implications

The mind map presented in Figure 35 represents the speculative scenario for streaming platforms developed by the group.

In the current scenario of streaming platforms, five main trends were identified, revealing possible directions for the future of this ecosystem, with varied implications in terms of probability, magnitude, and impact.

The first trend, the use of AI, presents a wide range of implications. Among the positive ones, with high magnitude and plausibility, is the acceleration of the process of producing films and series, affecting the technological domain. However, there are equally plausible negative implications, such as the production of less original and more generic works, impacting culture. In addition, implications classified as desirable, with great impact but low probability of realization, emerge, such as the use of AI as an auxiliary tool in the creative process without taking control of the foundations of creation. Equally desirable is the reduction of production costs for films and series, with positive economic impacts.

Figure 35: Speculative scenario: Streaming Platforms in 2029 (Group 3).



Source: Author's elaboration.

The second trend, which concerns new limitations on screens, presents as a negative aspect the reduction of user freedom in the use of services, affecting their behavior.

The group also identified the increase in piracy as a trend that produces a negative effect on the revenue of streaming companies, producers, and other agents in the content creation and distribution chain.

The fourth trend, related to a type of segmentation that leads streaming platforms to offer unique and niche content, is associated with enabling the creation of interactive and innovative productions based on such content, directly affecting the technological domain.

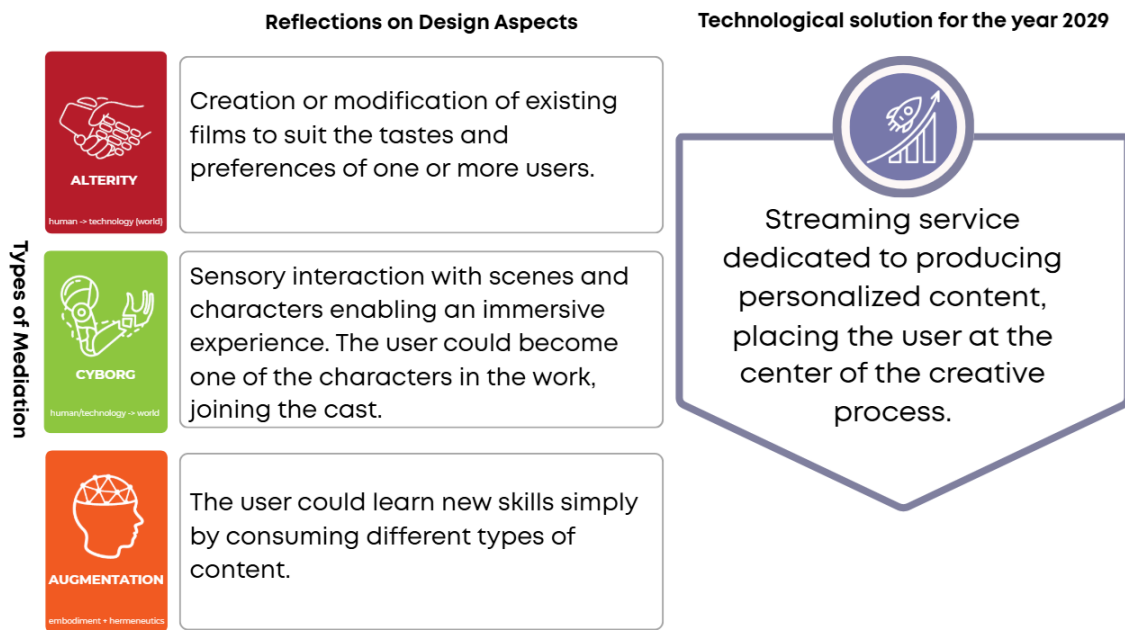
Finally, the fifth trend refers to the increase in advertisements on streaming platforms. This change could reduce subscription prices, an effect considered positive with medium impact and high probability of occurrence. It could also broaden access to the service and generate effects in the economy.

7.4.2 Speculation of the Technological Solution

Although the solution conceived by Group 3 is more generalist in nature and emphasizes the centrality of the user in content production, it relies heavily on the speculations developed during the exploration of the Technological Mediation Cards, as

illustrated in Figure 36.

Figure 36: Proposed Solution: Streaming Platforms in 2029 (Group 3).



Source: Author's elaboration.

The mediation of **alterity** inspired the idea of films that dynamically adapt to individual preferences. The **cyborg** mediation supported the proposal of sensory interactions with characters, enhancing the user's immersion in the narrative. The mediation of **augmentation** led to the conception that content consumption could also become a means of acquiring new skills. This influence of the mediations becomes even more evident in the section that explores the futuristic narrative developed by the group.

7.4.3 Alignment with the Main Objectives

Group 3 chose to focus exclusively on negative implications, proposing strategies to mitigate them. The solutions developed for each implication are summarized in Table 19.

Table 19: Proposed solutions for the implications, categorized by implication codes (Group 3).

Impl. Code	Solution for the Implication
3	To minimize the use of AI for generating overly generic stories, the models should be trained with a broader diversity of narratives, and human involvement in scriptwriting should be required, leaving only the most mechanical tasks to AI.
6	All content created by the streaming platform can be tracked through a watermark that carries embedded information. Additionally, noise is applied whenever inappropriate content is detected.
7	Content created by individuals can be shared with anyone they choose, with no screen limitations.

Source: Author's elaboration.

Implication 3, which highlights the risk that the use of AI in content production may result in more generic works with reduced originality and authorship, was mitigated

through the recommendation to train AI models with a more diverse repertoire of stories and narratives. The group also proposed maintaining the active presence of human screenwriters in creative stages and assigning only the most mechanical tasks to AI.

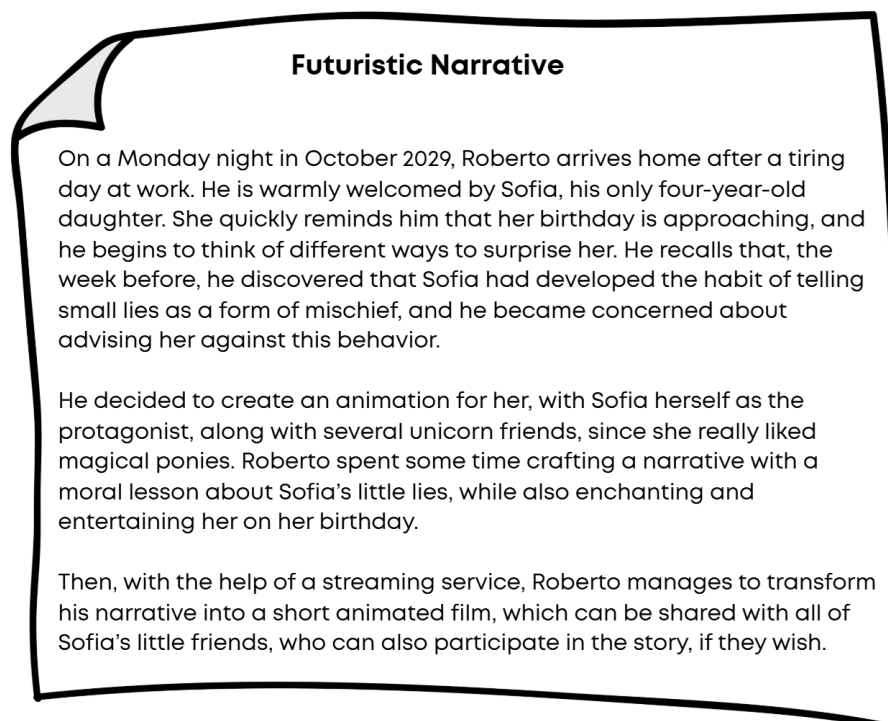
Implication 6, related to the increase in piracy and its economic impacts on streaming companies and other agents in the production chain, was mitigated by adopting content-tracking mechanisms through information-embedded watermarks and applying digital noise whenever improper use was detected, thereby hindering illegal reproduction.

Finally, **Implication 7**, which concerns screen-sharing limitations and their interference with subscribers' freedom, was mitigated by proposing that content produced by individuals could be shared freely, without restrictions on the number of authorized screens.

7.4.4 Futuristic Narrative and Shared Responsibilities

Figure 37 presents the futuristic narrative developed by Group 3, set in October 2029, in which a father named Roberto creates a personalized animated story for his daughter Sofia. In this scenario, the imagined technology is a platform powered by artificial intelligence that transforms personal narratives into interactive animations, with functionalities that enable collaborative storytelling.

Figure 37: Futuristic narrative (Group 3).



Source: Author's elaboration.

Subsequently, responsibilities were distributed across the sociotechnical network. Streaming services, developers, and users were assigned distinct roles to maintain a

balance between automation and human creativity.

Table 20: Responsibilities assigned to different actants, categorized by implication codes (Group 3).

Impl. Code	Responsibilities of the Actants
1	Streaming service: Commitment to the development of interactive content. User: Willingness to follow the platform's instructions and make full use of the experience.
2	User: Willingness to tolerate the inconvenience of advertisements in exchange for lower prices. Streaming service: Apply this strategy in a balanced manner so as to minimize user discomfort.
3	Developer: Use models trained with diverse datasets collected ethically. User: Engage in creative work when crafting prompts.
5	Developer: Manage generative content activity in ways that do not diminish the user's creative influence. Streaming service: Promote content that includes human participation.

Source: Author's elaboration.

To enhance the advantages of Implication 1, which concerns the growing production of unique content that supports the creation of interactive films and series, the streaming service is assigned the responsibility of investing in and committing to the development of content that increases audience immersion and participation. The user, in turn, is responsible for being willing to follow the platform's instructions and engage actively with the available functionalities, fully exploring the experience offered.

To strengthen the advantages of Implication 2, which addresses the increase in advertisements as a means of reducing subscription prices and expanding access to streaming services, the user is assigned the responsibility of tolerating the inconvenience of advertisements in exchange for lower costs. The streaming service, in turn, must apply this strategy in a balanced manner, minimizing discomfort and preserving the quality of the user experience.

To mitigate the effects of Implication 3, which warns of the risk that the use of AI in content production may render works less authorial, more generic, and with reduced originality, the developer is assigned the responsibility of training models with diverse datasets obtained ethically, thereby expanding the plurality and authenticity of the outputs. The user, in turn, is responsible for engaging in creative work when crafting prompts, actively contributing to ensuring that the final result preserves artistic identity and originality.

Finally, to realize the desired scenario associated with Implication 5, which envisions the use of AI as a supporting tool in the production of films and series without replacing the foundations of the creative process, the developer is responsible for managing generative content activity in ways that preserve the user's creative influence. The streaming service, in turn, is responsible for promoting productions that maintain human participation in key stages of creation, ensuring that technology complements rather than replaces artistic authorship.

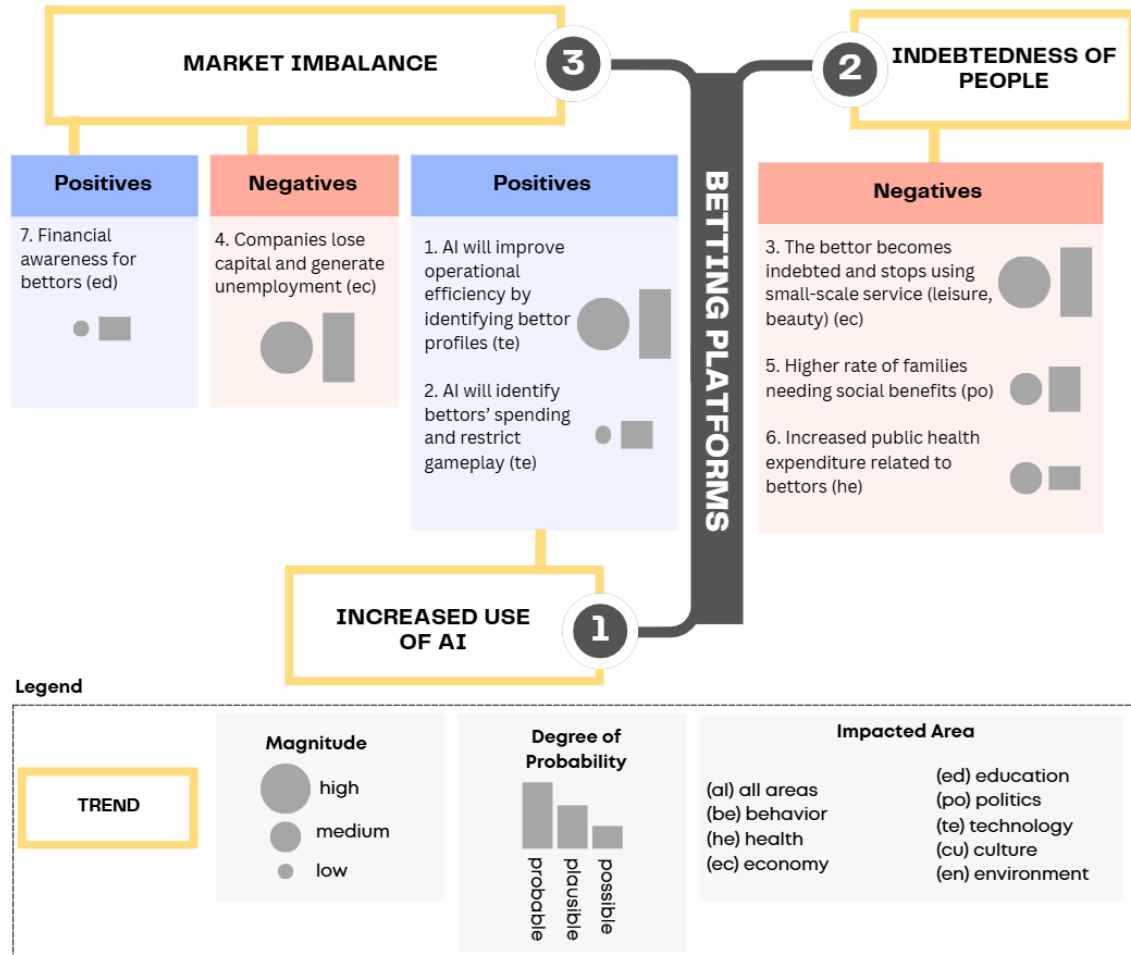
7.5 Betting Platforms - BETs (Group 4)

Group 4 investigated the domain of Betting Platforms, projected for the year 2026, following all the stages established in the workshop.

7.5.1 Current Scenario and Future Implications

The group identified three main trends, presented in Figure 38.

Figure 38: Speculative scenario: Betting Platforms — BETs (Group 4).



Source: Author's elaboration.

Regarding the trend of increasing use of AI in the operation of betting platforms, should it materialize by 2026, the group identified two positive implications with technological impacts. The first is the improvement of operational efficiency, enabling the identification of bettors' profiles and the optimization of service management, which was assessed as having high impact and high probability of occurrence. The second is the enhancement of expenditure monitoring, with the possibility of blocking gameplay when risk patterns are detected, functioning as a preventive measure against indebtedness. This latter implication, however, was perceived by the group as having low impact and low probability of occurrence.

The trend of progressive indebtedness among users of betting platforms is associated with at least three negative implications. First, bettors may reduce consumption of small-scale services related to leisure, beauty, and other areas, generating economic impacts. Second, there will be a significant increase in the number of families dependent on social benefits, placing pressure on public policies. Finally, public spending on health services

is expected to rise due to physical and psychological problems resulting from gambling addiction.

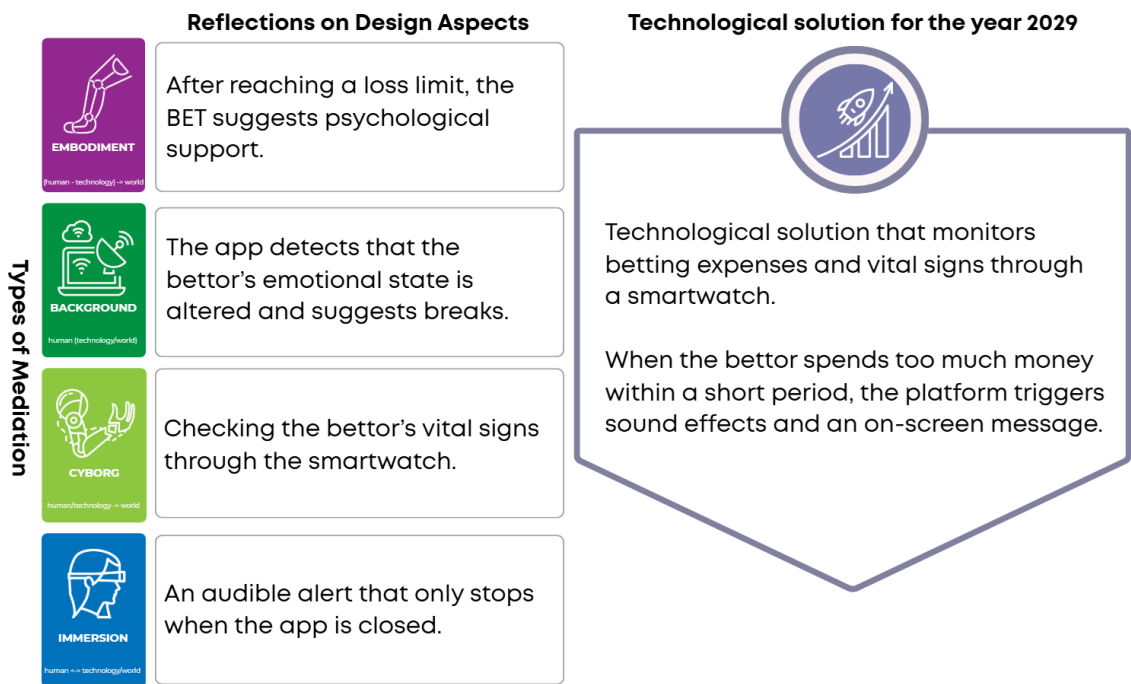
Concerning the trend of market imbalance, one positive implication was identified: financial awareness directed at bettors, which reveals an educational gap to be addressed. However, there is also a significant negative consequence, since companies in the sector may lose capital and generate unemployment.

Additionally, the group recorded in Notebook 2, although outside the direct scope of the workshop, the identification of those who would be benefited and those who would be adversely affected by each implication. For Implication 1, which anticipates the use of AI to improve the identification of bettors' profiles, the main beneficiary would be the company that owns the betting application (BET). For Implication 2, which uses AI to track spending and block gameplay, the primary beneficiary would be the bettor. For Implication 6, which concerns the increase in public health expenditures, both the bettor and the government would be the most negatively affected.

7.5.2 Speculation of the Technological Solution

The solution conceived by Group 4 is grounded in the speculations generated from the Technological Mediation Cards, as illustrated in Figure 39.

Figure 39: Proposed solution: Betting Platforms in 2026 (Group 4).



Source: Author's elaboration.

The **embodiment** mediation inspired the functionality of suggesting psychological support to the bettor after reaching a loss threshold. The **background** mediation guided the application's detection of changes in the user's emotional state, suggesting strategic pauses. The **cyborg** mediation supported the verification of vital signs through a

smartwatch. Finally, the **immersion** mediation inspired the inclusion of persistent auditory warnings that cease only when the application is closed.

These reflections resulted in the conception of a technological solution for 2026 that simultaneously monitors both betting expenditures and the user's vital signs through a smartwatch. If the system detects excessive spending within a short period, the platform triggers sound effects and on-screen messages to promote awareness and preventive intervention.

7.5.3 Alignment with the Main Objectives

Group 4 presented, in Table 21, the strategies adopted to mitigate negative implications and enhance positive ones associated with the proposed solution.

Regarding **Implication 3**, which relates to bettors' indebtedness, the betting application would be able to alert users whenever they reach a predefined loss limit within a specific period.

To mitigate **Implication 6**, which concerns the rise in public health expenditures resulting from gambling addiction, the group suggested implementing awareness campaigns about the risks associated with betting platforms.

Finally, to strengthen **Implication 7**, which involves the financial awareness of bettors, the group proposed that the betting application issue alerts about accumulated losses and proactively recommend seeking psychological support.

Table 21: Proposed solutions for the identified implications (Group 4).

Impl. Code	Solution for the Implication
1	N/A
2	N/A
3	Alerting the bettor when a loss threshold is reached within a given period.
4	N/A
5	N/A
6	Awareness campaigns about the risks associated with betting platforms.
7	Loss alerts and recommendations for psychological support.

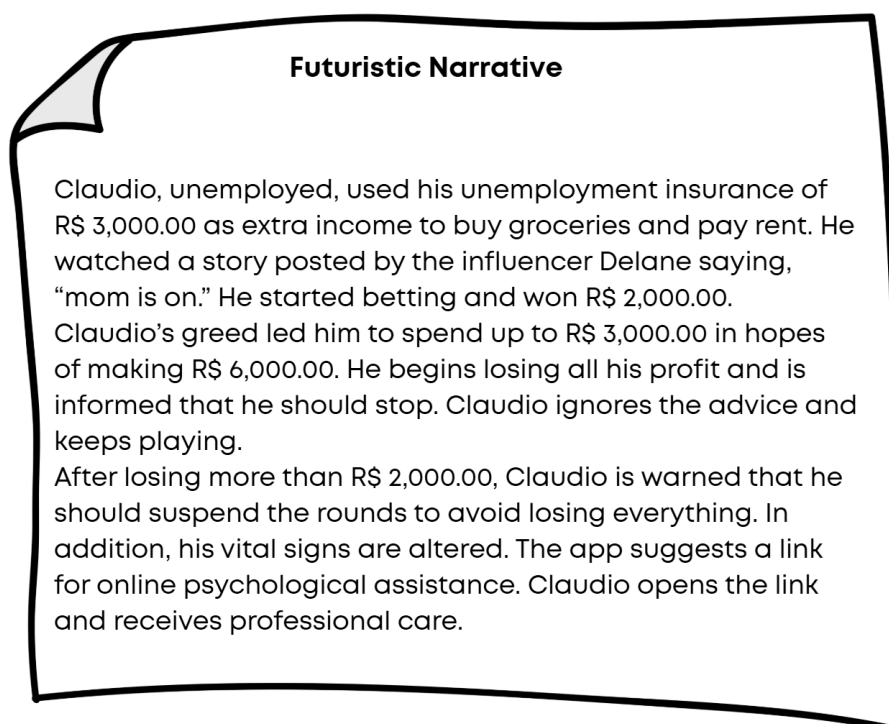
Source: Author's elaboration.

7.5.4 Futuristic Narrative and Distribution of Responsibilities

Figure 40 presents the futuristic narrative developed by Group 4, in which Claudio, who is unemployed, uses his unemployment insurance to place BETs after being influenced by a story posted by an online influencer. Following initial gains, he increases the risks, ignores alerts to stop betting, and accumulates significant losses. The system detects changes in his vital signs and suggests seeking online psychological support. Although not mentioned explicitly, the smartwatch is the device responsible for monitoring these signals and enabling the intervention.

Finally, the group outlined the distribution of responsibilities among the main actants. This overview is presented in Table 22.

Figure 40: Futuristic narrative (Group 4).



Source: Author’s elaboration.

Table 22: Responsibilities assigned to different actants, categorized by implication codes (Group 4).

Impl. Code	Responsibilities of the Actants
1	Platform: Monitor spending, timing, and betting patterns in order to alert users. Bettor: Accept the warnings and interrupt gameplay.
6	Government: Establish laws that prohibit advertisements related to betting platforms. Bettor: Become aware of the associated risks.
7	Platform: Indicate when the bettor needs assistance. Bettor: Acknowledge the need for help. Therapist: Raise awareness about the risks.

Source: Author’s elaboration.

In the case of positive Implication 1, which concerns the improvement of operational efficiency through the identification of bettors’ profiles, the platform assumes responsibility for monitoring expenditures, time of use, and betting patterns, using this information to issue preventive alerts. The bettor is expected to accept these warnings and interrupt gameplay when necessary, ensuring that the technological resource fulfills its protective purpose.

Regarding negative Implication 6, which refers to the increase in public health expenditures resulting from problems associated with gambling addiction, the government is responsible for implementing regulatory policies, such as prohibiting advertisements related to betting platforms, thereby reducing harmful stimuli. The bettor must become aware of these risks, contributing to the reduction of health impacts and, consequently, pressures on the public system.

For positive Implication 7, which addresses bettors' financial awareness, the platform must identify moments when the player needs assistance and indicate the availability of specialized support. The bettor must acknowledge this need and seek help, while the therapist plays the role of raising awareness about risks and reinforcing self-regulation practices.

7.6 Final Considerations of the Chapter

The speculations presented throughout this chapter show that the groups were able to carry out the activities proposed in the workshop and develop future scenarios grounded in the SEF tools. Each team mobilized, to varying degrees, the Sociotechnical Board, the Implications and Possibilities Wheels, the Technological Mediation Cards, and the Support Notebooks, demonstrating their ability to articulate trends, implications, and propositions for technological intervention.

Group 1, exploring dating applications and relationship platforms, conceived the Rudá platform, which integrates AI, VR, and IoT to create hybrid and safe experiences oriented toward support networks. Their proposal articulated behavioral, economic, and political implications with an ethical distribution of responsibilities among users, developers, government actors, and AI systems.

Groups 2 and 3 addressed streaming platforms and offered contrasting readings of the roles of immersion and personalization: Group 2 emphasized a service sensitive to emotional and sensory states, anchored in devices such as Istar and in narratives highlighting the agency of non-human actants in everyday domestic life, whereas Group 3 designed a platform oriented toward the co-production of interactive content, combining GenAI with user creativity and proposing mitigation mechanisms for risks such as piracy, cultural homogenization, and loss of authorship.

Group 4 examined the ecosystem of betting platforms, highlighting the impacts of indebtedness, health-related risks, and the use of AI to manage bettors' profiles. Their proposed solution focused on the monitoring of expenses and vital signs, as well as preventive alerts, articulating responsibilities among platforms, government agencies, bettors, and health professionals.

The degree of completeness across the stages varied among the groups. Some progressed through all phases in an integrated manner, from the initial speculation to the development of the technological solution, its rationale, and the distribution of responsibilities in the envisioned future ecosystem. Others exhibited gaps in specific stages, such as the alignment between implications and the features of the proposed solution or the detailing of responsibilities assigned to different actants.

Despite these differences, all groups produced analytically relevant material to a greater or lesser extent. These results provide the basis for the interpretations presented in the following chapter.

8. Results

This chapter compiles and organizes the results derived from the data analysis conducted according to the procedures described in Chapter 6, as well as from the speculative scenarios developed by the groups and systematized in Chapter 7.

Quantitative data are presented regarding the composition of these ecosystems (number of human and non-human actants, forms of agency attributed to them, identified trends), the future implications distributed across different areas of social life, the types of technological mediation activated by the groups, and the distribution of responsibilities between humans and non-humans in the projected scenarios.

In addition to this overview, the chapter presents how these results articulate with the post-anthropocentric principles of the SEF, showing how participants recognized the representativity of actants, understood artifacts as mediators of human action, approached reality in relational terms, and addressed uncertainty through speculation. Finally, the chapter presents records of participant engagement and perceptions regarding the workshop and the tools employed, based on the responses to the applied questionnaire, offering indications about the formative and critical potential of Speculative Design in the context investigated.

8.1 Exploration of the Sociotechnical Landscape

The initial analyses focused on mapping the number of human and non-human actors, the forms of agency attributed to them, and the emerging trends associated with the sociotechnical ecosystems represented on the Sociotechnical Board. The resulting data are presented in Table 23.

Table 23: Summary of the initial results.

Group	Theme	Humans	Non-humans	Human agency	Non-human agency	Mapped trends
G1	Dating Applications	3	10	6	11	4
G2	Streaming Platforms	6	7	2	4	3
G3	Streaming Platforms	3	9	6	12	5
G4	Online Betting Platforms	5	10	7	9	3

Source: Author's elaboration.

In total, the participants identified 17 human actors and 36 non-human actors, indicating a clear emphasis on recognizing technological, institutional, and infrastructural elements as integral components of sociotechnical ecosystems. A total of 21 instances of human agency and 36 instances of non-human agency were recorded, reflecting a strong tendency to acknowledge the capacity of non-human entities to influence and act within these ecosystems. Across all groups, 15 emerging trends were identified, with variations in quantity and focus.

A quantitative survey of the future implications mapped through the Sociotechnical Implications Wheel and the Possibilities Wheel was conducted, as presented in Table 24.

Table 24: Quantitative distribution of future implications mapped by area.

Area	Group 1	Group 2	Group 3	Group 4	Total
Behavior	5	3	1	0	9
Economy	2	1	3	2	8
Technology	2	0	3	2	7
Education	2	2	0	1	5
Health	2	1	0	1	4
Politics	2	1	0	1	4
Culture	2	1	1	0	4
Environment	2	0	0	0	2
Total per Group	19	9	8	7	43

Source: Author's elaboration.

All areas were addressed in the extrapolations of future implications; however, only Group 1 identified implications in all areas of the Sociotechnical Implications Wheel. It is noteworthy that the areas of behavior, economy, and technology presented the highest number of future implications, with 9, 8, and 7 occurrences respectively. In contrast, the environment was the least explored area, with only 2 mapped implications, both identified by Group 1.

In addition, Table 25 presents the quantitative distribution of the types of technological mediation explored by the groups when engaging with the Technological Mediation Cards.

Table 25: Types of mediation addressed by group and total occurrences.

Type of Mediation	Group 1	Group 2	Group 3	Group 4	Total Yes
Cyborg	Yes	Yes	Yes	Yes	4
Alterity	Yes	Yes	Yes	No	3
Augmentation	Yes	Yes	Yes	No	3
Hermeneutic	Yes	Yes	No	No	2
Background	Yes	No	No	Yes	2
Immersion	Yes	No	No	Yes	2
Embodiment	No	No	No	Yes	1
Total "Yes" per group	6	4	3	4	17

Source: Author's elaboration.

All types of technological mediation were addressed, with Group 1 identifying the greatest variety of types. The "Cyborg" type was the most frequent, with 4 occurrences, whereas the "Embodiment" type was the least frequent, with only 1 occurrence.

Finally, Table 26 presents the distribution of responsibilities among the actants mapped in Support Notebook 5.

It is observed that Groups 1 and 2 assigned significantly greater weight to non-human actants. Group 3, in contrast, emphasized greater responsibility attributed to humans, while Group 4 presented a balanced distribution between humans and non-humans.

Table 26: Quantitative distribution of responsibilities.

Group	Human Actants	Non-human Actants	Qty. Humans	Qty. Non-humans
Group 1	user, shopkeepers	AI, Feedback Systems, App, DEV Company, Information Security Policy, Government	2	6
Group 2	user, child's parents	AI, DEV Company, Regulatory Agencies, Device, Recommendation System	2	5
Group 3	user, developer	streaming service	2	1
Group 4	bettor, therapist	platform, government	2	2

Source: Author's elaboration.

8.2 Post-Anthropocentric Perspectives

This section presents the results interpreted in light of the post-anthropocentric principles and the workshop evaluation criteria described in Chapter 6, examining how these principles emerged in the proposals developed and how they contributed to reconfiguring the understanding of relationships between humans, non-humans, and technologies.

8.2.1 Principle P1: Representativity of Actants

The application of the SEF demonstrated a significant impact on how participants recognized and represented the agency of non-human actors. In addition to supporting the construction of future scenarios, the SEF fostered the decentralization of agency and encouraged the groups to acknowledge a plurality of entities capable of influencing and shaping interactions. In this process, technical artifacts, sensors, algorithms, digital platforms, virtual reality devices, and public policies came to be understood as active participants within the ecosystems investigated.

To assess how the SEF contributed to the emancipation of non-humans as active constituents of sociotechnical realities and futures, the relative presence of human and non-human actors throughout the speculative processes conducted by the groups was examined.

The analysis of Table 23 shows that all groups attributed agency to non-humans, although in different quantities. Group 3 stood out by identifying nine non-human actants and twelve instances of non-human agency, reflecting a consistent perception of how systems, algorithms, and platforms operate as mediators in interactions. Group 1, although identifying only three humans, mapped ten non-humans and eleven instances of non-human agency, demonstrating a strong emphasis on technological centrality in the context of dating applications. Group 4 mapped five humans and ten non-humans, with a relatively balanced distribution between human and non-human agency (seven and nine, respectively), revealing attention to shared responsibilities in online betting contexts. Group 2 recorded six humans and seven non-humans but presented only two instances of human agency and four instances of non-human agency, which suggests a more limited perception of distributed agency.

8.2.2 Principle P2: Artifacts as Mediators of Human Action

Table 25 shows that, across all groups, 17 instances of mediation types were identified, with emphasis on the “Cyborg” category, recognized by all four groups, and on “Alterity” and “Augmentation”, each present in three groups. Group 1 presented the highest number of occurrences (6), followed by Groups 2 and 4 (4 each) and Group 3 (3). These data indicate that participants acknowledged different ways in which technological artifacts not only mediate but also constitute human practices, affecting perceptions, interactions, and decision-making processes.

Group 4 proposed the use of a smartwatch to monitor the vital signs of a better, triggering pauses in the activity and suggesting remote psychological support. In this case, the platform interprets, alerts, guides, and recommends actions, directly influencing human behavior and the decision-making process.

Groups 2 and 3 reinterpreted streaming platforms not only as content delivery channels but also as modulators of lived experience. Group 2, for example, envisioned a streaming platform capable of reconfiguring aesthetic and sensory experiences by adapting color, brightness, and sound to accommodate users with light sensitivity or color blindness. This approach recognizes that the artifact directly alters how the world is perceived, expanding or constraining sensory possibilities and significantly affecting emotional states.

Group 3, on the other hand, imagined streaming as a space of affective creation in which users could transform personal stories into interactive media. The fictional narrative of Roberto creating a personalized animation for his daughter Sofia illustrates mediation as co-authorship. The artifact becomes an active participant in the creative process, with the AI functioning both as an executor of tasks and as a partner in constructing the narrative. In this case, human agency is deeply entangled with the operation of the system.

Interestingly, in Group 1, which worked with the theme of dating platforms, this awareness emerged through the application of the “alterity” mediation type to conceive an application aimed at providing emotional support in toxic interactions. The proposal involved identifying manipulative, aggressive, or sexist discourse and assisting users in formulating appropriate responses (Figure 30). In this scenario, perception and reaction are shaped by algorithmic filters, automated classifications, and suggestions that reconfigure the relational experience. The user does not interpret or decide in isolation; rather, they come to understand both the other and themselves through a technological layer that guides judgments and behaviors.

This example illustrates how the groups began to recognize that technological artifacts establish norms, modulate emotions, participate in the construction of meaning, organize experiences, and influence both decision-making processes and the formation of subjectivities.

In this context, mediation ceases to function as a simple intermediary and becomes a constitutive element of lived reality. This observation reflects the core of Principle P2, according to which human agency is continuously shaped, mediated, and performed in simultaneity with non-human elements. By structuring the speculative design process

from this perspective, the framework made this understanding not only possible but unavoidable for the participants.

8.2.3 Principle P3: Relational and Non-totalizing Reality

The analysis of the areas affected by the future implications, as presented in Table 24, shows that the agencies generating phenomenological implications are distributed across multiple dimensions of everyday life, often linked to more than one area. Groups 1 and 2 stood out for exploring a greater diversity of dimensions, avoiding the restriction of their speculations to isolated categories. Group 1, for instance, emphasized the behavioral dimension, which is intrinsically human, identifying five implications, while Group 2 highlighted three implications in the same dimension. Both groups, however, expanded the scope of analysis by including political and cultural aspects, bringing the discussion beyond immediate functionality and the instrumental use of technology.

The relational nature is also manifested in the connection between the projected solutions and the actants within specific situated contexts, addressing only certain layers of reality. Group 1, when addressing dating platforms, focused on interpersonal relations mediated by applications, particularly on discursive toxicity, emotional support, and peer networks. Although they identified relevant trends and proposed sophisticated solutions based on mediations such as real-time translation and automated emotional support, their analysis remained strongly centered on individual and behavioral dynamics.

Group 2 envisioned a sensory streaming service capable of adapting the user's physical environment, an ambitious proposal that incorporated physiological, perceptual, and emotional dimensions. However, the focus on hyper-personalization risks reinforcing a conception of reality as entirely configurable and malleable. This perspective overlooks the power structures that determine what can or cannot be customized, and who has access to such capabilities. Moreover, by positioning the user as the primary locus of experience, the group eclipsed the invisible labor required to sustain such technologies: digital health workers, developers, content moderators, infrastructure providers, and others who were not represented in the mapped network. In this scenario, reality is portrayed as infinitely responsive to individual needs, while systemic conditions and collective actors follow the logic of convenience and consumer individualism.

Group 3 proposed a streaming platform in which users could transform personal stories into interactive animations, creating affective narratives for themselves and others. Although imaginative and emotionally resonant, the proposal carries important contradictions. By assuming that anyone can become the author of their own narrative and circulate it as cultural content, the group endorsed a democratized view of technology that may not hold in practice. The analysis lacked critical engagement with algorithmic filters, representational patterns, or the creative constraints imposed by automated models. The system was treated as neutral, even though it incorporates intentionalities that remain beyond the user's control and were not problematized in the group's reflections.

Group 4, which explored betting platforms, demonstrated strong awareness of the social consequences of online gambling dependency. The group identified several

negative implications and proposed self-regulation mechanisms mediated by sensors and alert systems. However, despite recognizing user vulnerability, they did not question the structural logics of the betting industry itself, such as the monetization of attention, the legitimization of exploitative financial mechanisms, or the role of digital influencers in normalizing gambling practices. This interpretation nonetheless obscures the systemic conditions of an industry that profits from dependency.

8.2.4 Principle P4: Speculation in the Face of Uncertainty

The idea of a non-linear future and of uncertainty, including uncertainty regarding the understanding of the present, becomes evident in the work of Groups 2 and 3. Although they operated within the same thematic domain and shared the same starting point, each group began from different objective realities and activated different layers of subjectivation. Gaps in their understanding of reality led them to construct divergent worlds and, consequently, distinct futures. In this process, the use of the Sociotechnical Board, the identification of trends, and the formulation of future implications functioned as acts of creative imagination rather than simple descriptive exercises.

The Board itself, as a physical and bounded artifact, imposes a material delimitation on the complexity of a sociotechnical ecosystem. This constraint serves as a silent reminder that every representation of reality is inherently partial, situated, and uncertain. Faced with these limits, the groups filled the gaps beyond the edges of the Board, constructing connections between disparate elements and imagining relationships not yet made explicit.

8.2.5 Principle P5: Cosmopolitics in Support of Hybrid Constitution

Although the proposal of the SEF and its tools is grounded in the defense of a cosmopolitics of hybrids, the speculations developed by the four groups do not allow a clear assertion that participants recognized humans as part of a broader whole or as constituents of complex and interdependent ecosystems together with non-humans.

However, it is possible to observe that the productions reveal an understanding that the construction of desirable futures depends on recognizing the interrelations between humans and non-humans, even if an effective shift away from the centrality of human agency toward integrated ecologies did not occur.

An illustrative example of cosmopolitical activation can be found in the narrative of Group 1. In this scenario, the Rudá application operates as an active mediator in the interactions between Mia and Tainã, articulating multiple human and non-human actants within a hybrid ecology. From the simultaneous translation of conversations to the analysis of linguistic patterns for detecting toxic behaviors, Rudá does not merely provide a service but continuously negotiates meanings, emotions, and levels of safety between the parties. The decision to continue or interrupt the interaction does not belong exclusively to Mia or Tainã but emerges from an entanglement of detection algorithms, IoT devices, virtual reality functionalities, physiological sensors, and institutional guidelines embedded in the system.

This network of mediations creates a space in which music, scents, and landscape images become co-agents in shaping the encounter, expanding the affective experience and redefining boundaries between the intimate and the technological. By intervening when Mia's physiological signals fluctuate, suggesting actions and even the consumption of products, Rudá performs a form of distributed responsibility that involves both the preservation of well-being and the maintenance of commercial engagement, revealing the inseparability of care, desire, and market in the construction of this speculated future.

In the case of Group 1, this perspective materialized in a model in which users, algorithmic systems, mobile devices, platforms, and regulatory institutions assume complementary roles in preventing toxic interactions and promoting healthier relational environments. Here, responsibility is distributed across the sociotechnical network and not concentrated in a single decision-making pole. By recognizing that decisions, mediations, and forms of care emerge from the interactions among multiple agents, the group conceived a digital ecosystem whose governance is co-produced, bringing together technical and ethical practices aimed at sustaining regenerative and inclusive futures.

8.2.6 Principle P6: Sociotechnical Relations Producing Design with Shared Responsibility

Table 26 shows how the distribution of responsibilities between human and non-human actants was configured by the different groups. It is observed that, in all cases, responsibility is not concentrated in a single pole but emerges from the interaction among multiple elements.

In Group 2, responsibility emerged in the form of algorithmic cultural regulation, raising questions about bias and content diversity. In Group 3, it appeared as creative co-responsibility, requiring attention to distributed authorship and cultural rights.

In the case of Rudá (Futuristic Narrative of Group 1), responsibility is shared among the user Mia, her distant partner, the application, and the IoT-connected artifacts. This redistribution echoes the argument of Calderwood (2024) concerning the importance of developing a “posthuman critical literacy” that recognizes the co-authorship of computational and human agents. Simultaneous translation, IoT, VR, biometric sensors, and erotic artifacts actively participate in the construction of the bond, establishing a more-than-human fabulation that intertwines geographic distance and emotional intimacy, making it possible to imagine new affective configurations (Søndergaard *et al.*, 2023). However, the presence of Rudá as an active mediator, offering advice, regulating interactions, and suggesting products at the peak of a physical experience, introduces a tension that echoes concerns about how algorithms can assume normative roles and, in doing so, silently redefine parameters of behavior and value (Forlano; Halpern, 2023).

The Futuristic Narrative of Group 2, Istar from the perspective of the persona Galileu, performs a form of sensory care that also involves the cat Mimo, exemplifying the shift from representativity (“the represented cat”) to performativity, in which the animal actively participates in the phenomenon. This replacement of “representing” with “making-be” is central to the post-anthropocentric turn and aligns with the ethical shift proposed by Barad, in which responsibility and reality co-emerge (Barad, 2007).

The Futuristic Narrative of Group 3 presents an additional layer of complexity because it is a story within a story. At the external level, we see Roberto, a father, mobilizing technological resources to create a meaningful gift for his daughter. At the internal level, we have the magical fabulation of the unicorns, which performs a moral lesson about honesty. This metanarrative simultaneously accomplishes three movements: (1) it materializes a fictional world that acts upon the real world, in alignment with the idea of fabulation as a material-discursive practice (Søndergaard *et al.*, 2023; Jr; Lyytinen, 2017); (2) it operates as a counterfactual action (Cheon, 2023), offering an alternative scenario that teaches through prevention (Forlano; Halpern, 2023); and (3) it remains open to co-speculation, since other characters can be incorporated and the story can be collaboratively expanded (Wakkary *et al.*, 2022; Ståhl *et al.*, 2022). The result is a pedagogical staging that surpasses the boundaries of the screen, influencing the lived experience of the child and her social circle.

In the case of the Futuristic Narrative of Group 4, the performativity of the narrative reveals an ecology of care and risk, in which the betting platform, biometric sensors, and the link to psychological support co-produce the flow of actions, following a logic similar to the mediation of human relations discussed by Dörrenbächer *et al.* (2023).

8.3 Participant Engagement

Table 27 presents a set of results derived from the participants' responses to the questionnaire administered after the workshop Speculative Design - Building Bridges between Technology, Ethics, and Social Inclusion at IHC 2024. The purpose of this compilation is to identify the degree of participant engagement with the activities, tools, and dynamics proposed during the course, as well as to understand emerging perceptions regarding the concepts explored. Part of these results is revisited in the discussion section, in connection with other analytical elements and with the participants' own accounts, in order to deepen the interpretation of the findings.

Although the questionnaire provides relevant indications regarding participant engagement and perception, it presents a limitation related to the number of respondents, since only five participants completed the form. However, a second study (Loutfi *et al.*, 2025), conducted in another Speculative Design workshop and also structured according to the ARCS model (Keller, 1987), corroborated the findings presented here. In that study, a similar pattern of results was observed, with emphasis on the active involvement of participants, the strengthened understanding of the ethical and social implications of technologies, and the recognition of Speculative Design as an approach capable of expanding critical and creative reflection in educational contexts.

8.4 Final Considerations of the Chapter

This chapter presented the results obtained after the analysis of the data collected, compiled, and examined from the workshop detailed in Chapter 6. A panorama was organized that articulates, both quantitatively and qualitatively, the presence of humans

Table 27: Interpretive synthesis of the qualitative results of the workshop.

Analysis Axis	Interpretive Synthesis
Initial engagement and discovery	The absence of prior knowledge about Speculative Design fostered cognitive openness and an exploratory stance. The initial unfamiliarity functioned as a condition for more situated learning, allowing the artifacts to configure part of the meaning-making process.
Most striking elements (attention and involvement)	The tools, especially the Technological Mediation Cards and the Sociotechnical Implications Wheels, were perceived as active mediators of thought. They materialized abstract concepts and promoted critical reflection on the distribution of agency between humans and technologies.
Moments of surprise	The brainstorming and future-imagination stages provoked perceptual destabilizations. These moments of estrangement enabled the recognition of indeterminacy and the co-constitution of the real.
Relation to professional and academic context	The workshop was understood as a space that broadened the critical and ethical perspective on technological development. Participants connected the concepts learned to professional practices, recognizing the value of speculative design for understanding sociotechnical implications.
Ethical and social issues in the field of activity	Ethics and social inclusion emerged as central axes of reflection. Design was perceived as a political practice and as a means of promoting shared responsibility within technological ecosystems.
Skills developed	There was a strengthening of confidence in applying SEF tools, identifying sociotechnical agents and implications, and designing more relational futures. The tools were seen as mediators of learning and not merely as instruments.
Reflection and future projection	The workshop enhanced the capacity to think critically about uncertainty and to project possible futures. Speculation was recognized as a valid method for engaging with sociotechnical complexity and indeterminacy.
Valued aspects and improvements	The collaborative dimension and the collective construction of meaning were the most valued aspects. The limited time of the workshop was seen as a constraint for deepening reflections and consolidating learning.
Recommendation and dissemination of the practice	All participants recommended the workshop, recognizing its creative, interdisciplinary, and ethical potential. The course was perceived as a catalyst for a cosmopolitical and post-anthropocentric sensibility.

Source: Author's elaboration based on responses to the questionnaire from the workshop *Speculative Design - Building Bridges between Technology, Ethics, and Social Inclusion*.

and non-humans, the forms of distributed agency, the emerging trends, the projected future implications, and the distribution of responsibilities within the ecosystems explored.

The results revealed the centrality of non-human elements in the mapped sociotechnical networks, evidenced both by the number of actants and types of mediation identified and by the diversity of implications attributed to technologies, institutions, and infrastructures. It became clear that, across all groups, agency was conceived as relational, crossing boundaries between humans and non-humans and configuring hybrid ecologies of action. Furthermore, the analysis showed how the participants' speculations were articulated across multiple dimensions, such as behavioral, economic, political, cultural, and technological, albeit with varying emphases and gaps.

The compilation and interpretation of the data also made it possible to observe patterns of shared responsibility, indicating that decisions and consequences do not fall upon a single pole but emerge from the entanglement of multiple actants. In this sense, the results reinforce the post-anthropocentric principles that guided the workshop, by demonstrating that imagining futures requires considering not only human creativity but also the performative and normative roles of algorithmic systems, technical devices, public policies, and other non-human elements that participate in the construction of reality.

9. Discussion

This chapter develops a discussion grounded in an interpretive analysis, complemented by a diffractive analysis. The interpretive analysis draws on the results of the Speculative Design workshop conducted at IHC 2024, triangulated with the theoretical foundations of Entanglement Theories, related work, and participants' accounts collected through the post-activity questionnaire. From this perspective, the discussion examines how post-anthropocentric principles manifested in the speculations and projected solutions, highlighting movements that made non-human actants visible, the techno-material mediation of human agency, the inherent incompleteness of representations of complex ecosystems, the role of collective sensemaking practices, the (still partial) activation of cosmopolitical sensibilities, and the redistribution of responsibilities between human and non-human entities. In a complementary movement, the chapter also discusses the entanglements among the philosophical currents that underpin the SEF, demonstrating how each contributes to the mapping, interpretation, and projection of sociotechnical ecosystems from a post-anthropocentric standpoint.

The diffractive analysis, which complements the analytical orientation of this research, is mobilized to bring data, theories, and contingent events into relation, treating them as interference patterns that reconfigure the very phenomenon under investigation. Throughout the chapter, for example, the discussion addresses how the power outage during the workshop, the evaluative instances of the dissertation, and the incorporation of GenAI into the writing process became part of the research apparatus, shifting the analytical gaze and enriching the reading of the intra-actions between participants, tools, theories, and artifacts. In this way, the discussion does not merely interpret results but makes explicit how the research trajectory itself becomes a constitutive part of the entanglement it seeks to understand.

9.1 Alignment with Post-Anthropocentric Principles

This section discusses the post-anthropocentric principles in light of the workshop's evaluation criteria presented in Chapter 6, examining how these principles manifested in the proposals developed by the participants and how they contributed to reconfiguring the understanding of relationships between humans, non-human actants, and technologies.

9.1.1 Impact of the SEF on the Visibility of Non-Human Actors

The SEF guides the design process through the continuous effort to make non-human agency visible. This orientation is supported by [Forlano e Halpern \(2023\)](#) and [Bekker *et al.* \(2023\)](#), who emphasize the importance of methodologies and tools acting as constitutive elements of sociotechnical ecosystems rather than as neutral instruments. This orientation is formalized in Principle P1, which proposes recognizing and foregrounding non-human actors at all stages of the design process.

During the workshop, this principle manifested across the speculations. Early in the activities, the Sociotechnical Board prompted the groups to identify the non-human actors present in the ecosystems and to explicate the forms of agency attributed to them. It is important to note, however, that the quantitative representation of actors and non-human agencies shown in Table 23 is not, in itself, sufficient to substantiate this analysis. The number of non-human entities identified by the groups does not necessarily translate into the depth of the discussions or the quality of the reflections regarding their agencies.

Even so, the attention given to non-human actants emerges in participants' statements. When responding to the question, "Which skills or knowledge acquired during the workshop do you feel confident applying?", one participant stated:

I feel confident applying the concept of involved agents and the implications of trends... (Participant 3).

Furthermore, when asked how they relate the concepts learned in the workshop to their professional or academic activities, one participant emphasized:

The concepts learned expand the knowledge base necessary for software development activities. They help in considering the current scenario of a given application, identifying relationships and stakeholders... (Participant 2)

In the phase of designing the interventionist solutions, the Technological Mediation Cards further enhanced the visibility of technological agency by guiding reflections on how artifacts, platforms, and algorithms may influence behaviors, decisions, and experiences. This tool was well received by the participants, as illustrated by the following statement:

The brainstorming activity using the Technological Mediation Cards was an unexpected exercise and proved to be surprisingly practical in supporting the developed solutions. Pushing beyond the limits of current technological capabilities and imagining unusual scenarios within the context of the problem was not only fun but also highly enriching. (Participant 2)

Although the facilitators emphasized that the groups could adopt the perspective of non-human personas, no group developed a narrative from the point of view of a non-human actant. This reveals the difficulty of shifting from an anthropocentric logic to a truly relational perspective. This result may be associated with the fact that narrating from such a standpoint requires greater cognitive effort, since it involves departing from a habitual human perspective toward a distinct relational and material logic. Moreover, the limited time allocated to the activity was identified by several participants in the questionnaire as a constraining factor, which may have contributed to this absence.

Even so, in the interventionist technological solutions they proposed, the groups assigned responsibilities and intentionalities to non-human entities, consolidating their presence as active participants within the speculated networks. In future workshops, it would be relevant to examine the extent to which these non-human representations undergo processes of anthropomorphization, a phenomenon that can be interpreted in light of correlationalism, since it highlights the tendency to understand the world only in relation to human experience. Such reflection would allow for a deeper exploration of the limits and possibilities of conceptualizing the non-human outside the centrality of the human in speculative narratives.

9.1.2 The Emergence of Human Agency as Mediated

Principle P1 permeated the entire speculative process, encouraging participants to recognize how human actors and technical, institutional, and material elements actively participate in the constitution of the sociotechnical ecosystems analyzed. This orientation supported Principle P2, according to which human action is never entirely autonomous and is continuously shaped by devices, interfaces, algorithmic systems, sensors, and other artifacts that qualitatively restrict or expand possibilities for action and perception. This understanding became particularly evident during the use of the Technological Mediation Cards, a tool that prompted participants to reflect on the ways technical artifacts actively contribute to sensemaking, experience, and human agency itself.

However, although Table 25 demonstrates the recognition of technological agency, in most cases there is no equally clear indication that the groups understood that these artifacts also mediate human agency. The projected solutions suggest an awareness that technology acts on behavior and decision-making, but it is still understood as an element that impacts people's lives rather than as a component that co-constitutes human action. This distinction is fundamental for understanding technological mediation because it involves recognizing that humans act with and through technology, not merely upon it.

It is also noteworthy that some participants acknowledged the mediating role of the Technological Mediation Cards in the act of designing, as illustrated by the following account:

The Technological Mediation Cards, because they stimulated creativity in imagining different solutions for the proposed scenarios... (Participant 3)

In this context, it is essential to develop mechanisms, whether through tools or through discursive practices facilitated by instructors, that promote deeper reflection on the role of technologies as mediators of human agency. In a scenario marked by the growing presence of GenAI technologies, understanding how these systems intervene in our ways of thinking, creating, and deciding becomes increasingly important.

9.1.3 The Incompleteness of Design in the Face of a Complex World

The analysis of Principle P3, which states that reality is relational and cannot be reduced to totality, presupposes the recognition that although the groups rigorously mapped networks of actors, their relations of agency, and the projected implications, none of them were able, nor could they fully capture, the complexity of the ecosystems explored. Each proposed solution, regardless of how rich or well articulated it may be, reveals both what was made visible and what remained unspoken or obscured. The SEF demonstrated its potential not only to expand participants' awareness of sociotechnical entanglements but also to highlight the limits of analytical and speculative perspectives when confronted with the real.

Interestingly, several participants associated this sense of incompleteness with the limited time available in the workshop, something that became evident both in group discussions and in the questionnaire responses, as illustrated below:

Regarding improvements, I think there could have been more time to carry out the activities. It was very rushed. (Participant 1)

The areas where I would need more support are sociotechnical analysis and the consolidation of the obtained results to conceive a concrete solution based on the defined timeframe. (Participant 2)

These perceptions reveal that the sense of incompleteness does not stem solely from the intrinsic complexity of the sociotechnical phenomenon but also from the material and temporal conditions that shape design practice.

In this regard, it is essential that facilitators emphasize that the incompleteness of reality extends far beyond the temporal limitations of the workshop. It arises from the contradictions and tensions inherent to design, which emerge precisely from what remains invisible, from the lack of critique of opaque infrastructures, and from the simplifications that portray users sometimes as rational agents and sometimes as passive recipients.

Facilitators should also reinforce that no matter how consistent the mapping of human and non-human actants in sociotechnical networks may be, the totality of reality always exceeds any attempt at representation. Biased tendencies frequently emerge from the effort to produce coherent, closed, and functional solutions. The impulse toward control manifests itself in attempts to stabilize systems and anticipate predictable futures, which reduces complexity to overly ordered models. Moreover, relational reality does not manifest only in the nodes and links represented but also in the noise, the deviations, and the resistances that escape analytical attention. Recognizing these hidden layers is essential for ensuring that the design process remains sensitive, reflective, and open to uncertainty.

Acknowledging incompleteness does not weaken the analysis. Instead, it reaffirms it as a procedural and unfinished practice, guided by continuous revision, attentive listening, and sensitivity to what remains invisible (Calderwood, 2024; Dörrenbächer *et al.*, 2023).

9.1.4 The Power of Collective Sensemaking Practices

Principle P4 emerges as a natural extension of Principle P3. Once it is recognized that reality is relational and irreducible to totalizations, it becomes evident that design cannot rely on definitive diagnoses or closed solutions. In this context, speculation becomes established as a critical and creative practice in the face of indeterminacy, enabling design to become a field of collective experimentation and reflection.

Benjamin *et al.* (2023) argue that zones of uncertainty challenge conventional notions of truth by creating opportunities for new aesthetic and epistemological experiences. In these liminal spaces, where neither humans nor algorithms possess full control over reality, the spectator is called upon to negotiate meanings together with other actors. By inhabiting such zones of ambiguity, participants are invited to reflect critically on what they see, how they see, and the ways in which technology actively participates in the production of reality.

This negotiation of meaning goes beyond the individual sphere and emerges through collective processes in which sensemaking occurs simultaneously with sensegiving, a

phenomenon described by Dixon *et al.* (2017) in the context of “in extremis” environments. In scenarios marked by high uncertainty and elevated risk, leaders engage both in interpreting and in shaping meaning, recognizing that interpretation and action must remain synchronized to support collective orientation. This reflective stance is echoed in the account of one participant:

I found it important for helping us think outside the box, but in a structured way. (Participant 1)

In this way, uncertainty assumes a methodological role, becoming a device for investigating the sociotechnical implications of perception and knowledge production. It involves assigning meaning to what is still emerging and constructing coherence amid multiplicity, an exercise that directly influences innovation, as highlighted in the following statement:

The practical dynamics made learning engaging and applicable, especially for those working with innovation. (Participant 4)

Therefore, when carried out collectively, this practice is strengthened by a shared subjectivity. From the outset, the imagined future is shaped by present conditions, interpreted from multiple points of view, and collaboratively constructed, revealing that speculative design is also a space where meanings, values, and worldviews co-emerge.

9.1.5 Activating the Cosmopolitics of Hybrids

The MtHD approach (Stead *et al.*, 2022) inspires the SEF to broaden the scope of design by recognizing that objects, organisms, and systems compose interconnected networks of relations in which flora, fauna, climate, and technical artifacts act jointly as co-agents within data flows and their sociotechnical effects. In this sense, the SEF and its tools foster the construction of regenerative futures and a pluriversal design (Dunbar; Speed, 2024).

Throughout all stages of the process, facilitators are responsible for guiding participants in the use of the tools and the framework in ways that encourage more sensitive, relational, and interdependent readings between humans and non-human actants. The emphasis lies in understanding that ethical and sustainable futures cannot be built through universal solutions but through coexistence and negotiation among multiple cosmologies and ontologies. Speculation should interrogate the nature of objects and technologies beyond the centrality of human and Western epistemic representations, seeking to avoid processes of defuturing (Blauvelt, 2020) and recognizing that sociotechnical decisions emerge and transform continuously within complex ecosystems.

This attention must begin in the mapping stage, when the ecosystem is described in ways that make interdependencies and mutual agencies visible. Tools such as the Sociotechnical Implications Wheel and the Possibilities Wheel should encourage practices of care, equity, and sociotechnical justice in the activation of desirable futures. To achieve this, facilitators should foster critical analyses of the implications identified and promote ethical, situated, and context-aware speculation.

During the design of the solution, the Technological Mediation Cards should operate

as devices of futurization (Bertmark, 2025), inducing perspective shifts toward an ecocentric vision and fostering more balanced socioecological relations. Finally, the materialization of the narratives should reinforce the notion of distributed and relational responsibility among all agents involved.

All these elements align with the concepts of hybridization and cosmopolitics, which must be enacted and activated throughout the design process. Although the groups had no prior familiarity with the notion of hybridization proposed by Haraway (2013a), which understands humans and non-humans as co-constituted entities within networks of interdependence, nor with the idea of cosmopolitics in Stengers (2010), which advocates for coexistence and negotiation among multiple forms of existence, signs of this sensibility can be observed in the productions developed during the workshop.

An illustrative example can be found in the narrative produced by Group 1. In this scenario, the Rudá application acts as an active mediator in the interactions between Mia and Tainã, articulating multiple human and non-human actants within a hybrid ecology. From the simultaneous translation of conversations to the analysis of linguistic patterns for detecting toxic behaviors, Rudá does not simply provide a service but continuously negotiates meanings, emotions, and levels of safety between the parties. The decision to continue or interrupt the interaction does not belong exclusively to Mia or Tainã, but emerges from an entanglement involving detection algorithms, IoT devices, virtual reality functionalities, physiological sensors, and institutional guidelines embedded in the system. This network of mediations creates a space in which music, scents, and landscape images become co-agents in configuring the encounter, expanding the affective experience and redefining boundaries between the intimate and the technological. When intervening in response to changes in Mia's physiological signals, suggesting actions and even consumption of products, Rudá stages a form of distributed responsibility that involves both the preservation of well-being and the maintenance of commercial engagement, revealing the inseparability of care, desire, and market dynamics in the construction of this speculated future.

9.1.6 Ethics and the Sharing of Responsibility

The facilitators, the participants, the tools, the SEF itself, and the space-time of the workshop compose an apparatus (Österlund *et al.*, 2020) that defines the conditions of possibility for the experience and articulates material agency, multistability, and transparency in the interactions among humans and artifacts (Kimura e Nakajima (2022)). These elements are therefore neither neutral nor external to the phenomenon. They actively participate in the production of possible realities, configuring the intra-actions that shape the phenomenon.

Given the multiplicity of actants and intra-actions, it becomes necessary to perform agential cuts to demarcate what will be considered relevant and what will remain outside the analytical focus. In the workshops, agential cuts were enacted by the participants themselves, who decided what would be made visible and what would be excluded from the phenomenon, delineating the discursive and material encounters perceived as significant.

The futuristic narratives produced with Notebook 4 of the workshop operate as

performative materializations resulting from intra-actions. These fabulations stage relations and redistribute agency and responsibility. This enactment aligns with what [Kong *et al.* \(2021\)](#) describe as experiential entanglement, in which narratives emerge as hybrid zones where the real and the fictional are co-produced, transforming memories, perceptions, and sensibilities.

This dynamic can be observed in the differences between the agential cuts, futuristic narratives, and distributions of responsibility produced by Groups 2 and 3, both focused on the domain of streaming platforms. Group 2 enacted an agential cut that emphasized algorithmic mediation as a central element of cultural governance, foregrounding recommendation systems as actants that regulate experience and symbolic value. Group 3, in turn, enacted agential cuts that highlighted the creative agency of users, enabling the audience to become co-authors of content. In both cases, agential cuts defined specific objects of attention from which new ethical and responsibility-related encounters emerged.

Within the relational ecologies [Dörrenbächer *et al.* \(2023\)](#) in which these cuts were embedded, the futuristic narratives staged negotiations around the redistribution of responsibility among actants. In Group 2, responsibility emerged as a form of algorithmic cultural regulation, raising concerns about bias and content diversity. In Group 3, responsibility manifested as co-creative accountability, requiring attention to distributed authorship and cultural rights.

9.2 Entanglements among Philosophical Currents

The following section discusses the conceptual entanglements among the philosophical currents that underpin the SEF, highlighting how each contributes to the mapping, interpretation, and projection of sociotechnical ecosystems from a post-anthropocentric perspective.

9.2.1 Actor-Network Theory and Speculative Realism in the Mapping of Sociotechnical Ecosystems

The Sociotechnical Board operates as a tool that makes visible the associations structuring the current sociotechnical ecosystem. By making explicit the actants and the connections that link them, it is grounded in a central principle of ANT: sociotechnical reality is a provisional outcome of heterogeneous networks composed of elements that interact and mutually co-constitute one another.

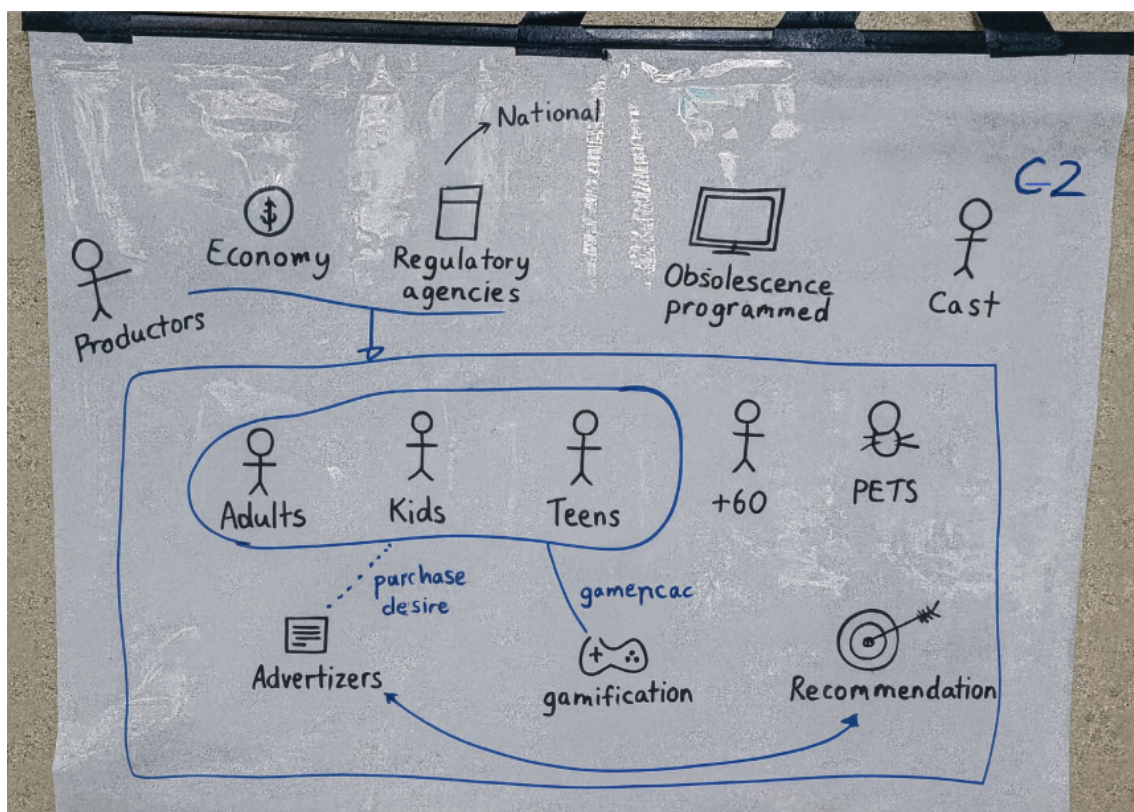
However, ANT is not applied in its entirety in this context due to constraints inherent to the field of IS. First, its emphasis on detailed and localized descriptions of networks makes its full adoption unfeasible in organizational environments marked by urgency and resource scarcity, such as agile IT projects ([Doolin; Lowe, 2002](#)). Second, ANT lacks analytical instruments capable of engaging with opaque entities such as proprietary algorithms, digital infrastructures, and autonomous systems whose agency cannot be fully traced ([Mwenya; Brown, 2017](#); [Doolin; Lowe, 2002](#)). Third, as argued by [Scott e Orlikowski \(2014\)](#), the approach presents limitations when dealing with objects whose

ontological autonomy exceeds their observable empirical relations, especially in situations where significant effects escape the type of tracing proposed by the methodology.

The growing opacity, ubiquity, and reconfigurability of digital technologies highlight the insufficiency of exclusively descriptive methods such as ANT and call for approaches that recognize the constitutive materiality and agency of artifacts beyond traceable associations. It is precisely in these zones of opacity that the uncertainty inherent to speculative accounts emerges, and it is at this point that the speculative dimension becomes a complementary approach by incorporating the interpretive and interventive orientation of Speculative Realism.

This interpretive openness brings the Sociotechnical Board closer to what [Bogost \(2012\)](#), in the context of Speculative Realism, refers to as ontography. An example can be seen in the board produced by Group 2 (Figure 41), which mapped heterogeneous existences without assigning them relevance subordinated to a human-centered perspective or to causal hierarchies. In practice, this mapping materializes an ontographic perspective by rendering visible the associations and interdependencies that compose an expanded, heterogeneous, and interconnected network of actants.

Figure 41: Sociotechnical Board of Group 2 (Streaming Platforms).



Source: Group 2 (English version, translated by ChatGPT 5.1, of the diagram produced in the Sociotechnical Board. The original Portuguese version is presented in Appendix D).

By prompting participants to map and critically reflect on the actants, the Sociotechnical Board encouraged a more relational and distributed understanding of

action and made actants visible even when their ontology and their role in the network were not fully understood. This contrasts sharply with the ANT approach, which presupposes following the actors and describing both what they do and how they make others act. At the same time, this departure strengthened participants' analytical capacity and expanded their sensitivity to dynamics that would otherwise remain invisible.

Although the collected data do not indicate this explicitly, the analysis suggests that an overly speculative and insufficiently descriptive perspective may lead to an over-relativization of the present reality, resulting in the projection of scenarios that become excessively distant from the current context.

9.2.2 Speculative Realism and Futures Design

The SEF cone, which expands from the present toward the future, does not aim to offer a totalizing representation of what is to come. Instead, it seeks to activate modes of knowing the future, reflecting on the present, and intervening in what is yet to emerge in order to support the development of scenarios considered desirable.

In this context, the future is treated as an object, following the perspective of OOO, which carries important implications. Emerging trends, weak signals, and current configurations provide clues that, when extrapolated through Speculative Design, allow glimpses into what the future may become.

In OOO, objects are not empty but possess qualities through which we relate to them. Thus, by treating the future as an object, the SEF understands it not as an indeterminate void but as a partially accessible entity whose qualities can be explored through situated speculation and through the relations we establish with it from the present.

The SEF cone retains its utility even when the goal of a speculative project is not to anticipate, predict, or intervene in the future but to propose alternatives for the present or for the near future. It enables a shift in perspective beyond the limits imposed by immediate business demands and supports the conception of more ambitious, responsive, and attentive solutions attuned to ongoing transformations. In practical terms, this may translate into the creation of provocative prototypes, usage narratives, critical user journeys, or impact simulations that serve as strategic inputs for guiding decisions in IS projects.

Throughout the speculative process, two central elements of OOO emerged: flat ontology, which decentralizes the human by assigning ontological equality to all entities, and the rejection of correlationalism, grounded in the possibility of accessing aspects of the real independently of human mediation.

In Group 1, for example, information security policies and automated mechanisms for detecting toxic speech were described as regulating instances endowed with their own capacity to shape interactions, including situations that escape the immediate perception of human participants.

9.2.3 Postphenomenology as an Extension of Agential Realism in the Evaluation of the Human-Technology-World Relation

Although this study does not present a specific theoretical-methodological tool for conducting diffractive analyses, this perspective is embedded within the framework. It is grounded in the assumption that material-discursive practices constitute the space in which ethics and responsibility emerge together.

Agential Realism focuses on the performativity and relational ontology of phenomena. By fostering the creation of narrative prototypes (Stahl *et al.*, 2022; Søndergaard *et al.*, 2023; Dörrenbächer *et al.*, 2023), critical objects (Encinas *et al.*, 2020), and future scenarios (Stead; Coulton, 2022; Oogjes; Wakkary, 2017), this approach seeks to dramatize the ethical, political, and ontological implications of technologies, anticipating consequences that are often obscured by hegemonic discourses of innovation. Postphenomenology, in turn, adds a distinct analytical emphasis on technological artifacts and their mediations in experience, aiming to reveal how such mediations shape perceptions, affects, decisions, and situated practices.

Therefore, within the context of the SEF, Postphenomenology can be understood as an approach situated within the broader contours of Agential Realism, contributing in a complementary way to diffractive inquiry by offering conceptual tools for understanding the specific effects of technical mediations.

9.3 Interference Patterns in a Diffractive Method

From this point onward, the discussion adopts a diffractive perspective, as proposed by Barad (2007), understanding that the act of knowing is part of the constitution of the phenomenon itself. The data are not treated as something external to be interpreted but as materialities that co-emerge with the researcher, the texts, the practices, the discourses, the artifacts, and the speculations, allowing them to pass through and transform one another.

Instead of presenting “findings” followed by interpretations, the aim is to foreground interference patterns, understood as effects, resonances, and phenomenological reconfigurations that emerge from intra-actions. Thus, rather than asking “what does this mean?”, the question becomes “what emerges from this encounter?”

9.3.1 Interference Pattern: Evaluative Intra-Actions and the Reconfiguration of the Analytical Gaze

During an evaluative moment in the trajectory of this research, a tension became evident between the discourse anchored in the entanglement-oriented approach and some of the modes of presenting the analysis in Chapters 8 and 9, which still reproduced a dichotomous structure close to the representationalism discussed in Section 2.5. This tension manifests itself, for example, in the quantifications presented in Tables 23, 25, and 26, in which the complexity of intra-actions tends to be translated into numbers and fixed categories.

Recognizing this tension constituted a diffractive interference pattern. By allowing the analytical process to be traversed by it, the research began to problematize the place of quantifications and to revisit the way traditional content analysis had been mobilized. Rather than treating these instruments as a conclusive and stabilizing stage, they were reinscribed as one among many possible agential cuts, highlighting that every reading is situated, partial, and materially conditioned.

From this understanding, the discussion presented here seeks to make more explicit the diffractive orientation that already underpinned the research, emphasizing that the different moments of reading, critique, and evaluation of the dissertation form part of the methodological apparatus itself. Evaluative instances are not taken as external corrections to the study but as discursive and relational materialities that co-constitute the phenomenon under investigation and thicken the interpretation.

Other interference patterns that emerged throughout this process are presented in the subsections that follow.

9.3.2 Interference Pattern: The Light That Goes Out and the Phenomenon That Lights Up

During the workshop, an unexpected event generated a new interference pattern: a power outage shortly before the closing activities. Although the loss of electricity had not been speculated as a trend or a specific possibility in the workshop planning (see Section 6.4.1), the prospecting process had identified the trend of potential delays or unforeseen interruptions in the schedule. For this reason, time buffers were planned in advance, and an alternative questionnaire was prepared to replace the focus group if the remaining time proved insufficient for its execution.

Thus, even though the blackout had no direct relation to the anticipated time-related risks, the mitigation strategies associated with that trend proved effective in the face of the unforeseen event. The questionnaire, initially designed to deal with temporal constraints, ultimately became useful for continuing data collection after the workshop was interrupted by the power outage. This experience shows that even when the exact nature of an unpredictable event cannot be anticipated, prospecting its possible effects may guide preventive practices that become valuable in unforeseen contexts. The initial plan envisioned a traditional closing sequence, with lessons learned, final remarks, and the execution of a semi-structured focus group. The absence of the projector, however, reconfigured the dynamics of the workshop, leading me to present the theories behind the tools in a more open, dialogical, and situated manner.

Paradoxically, the absence of light illuminated another path. The physical space was transformed: voices that had previously been silenced emerged, the environment became more relaxed, and the dialogue intensified. It was as if the presence of light had functioned as an object of control and centralization, and its disappearance opened room for a more affective and spontaneous participation.

At the same time, the focus group's cancellation resulted, in the initial analysis of the workshop, in the absence of a more systematic triangulation with participants' voices. Although the questionnaire was sent out after the workshop, its results had not, at first,

been fully explored as part of the analytical corpus.

In light of the diffractive perspective and of the recognition that multiple discursive materialities constitute the phenomenon, the analysis was subsequently deepened by more consistently incorporating the questionnaire data. In this way, both the workshop experience and the participants' later responses, along with the evaluative instances of the research, come to be understood as elements of a shared entanglement that continually reconfigures the conditions of possibility for interpreting the workshop and this dissertation.

9.3.3 Interference Pattern: Cognitive Reconfigurations with GenAI

GenAI became part of the research process only in 2024. A substantial portion of this dissertation, however, was developed without the use of this technology. During the qualification stage, the text was entirely authorial, the result of an individual effort of reading, writing, and conceptual development. The initial model of the dissertation was also conceived without the support of GenAI, requiring extensive theoretical immersion to understand the dense and multifaceted literature on Entanglement Theories. Reading the seminal works and assimilating their concepts demanded in-depth study, consultation of multiple sources, and long periods of introspection.

With the emergence of GenAI, I began to engage with it as a way of expanding thought. Ideas, conceptual questions, and hypotheses about the relations among theoretical constructs were continually revisited in dialogue with it. In this sense, GenAI became a partner in reflection, helping me understand, articulate, and refine complex concepts. It also played a role in the design of the framework and tools, and inspired the three fundamental questions that gave rise to the SEF, offering support for the organization and systematization of ideas. Its presence did not replace the earlier intellectual effort but expanded the possibilities for expression and for establishing connections among concepts.

It can be said that GenAI emerged at a moment of conceptual maturation in the dissertation, contributing decisively to the consolidation of ideas and to the refinement of the writing. This apparatus is understood as an intra-active actant whose agency participated in the co-constitution of the phenomenon that encompasses this work, its artifacts, and its conditions of production.

9.4 Final Considerations of the Chapter

The analysis presented in this chapter demonstrates that the SEF functions as a theoretical-methodological apparatus capable of articulating interpretive analysis, speculative practice, and diffractive reading in order to make visible the distributed agencies and shared responsibilities within sociotechnical ecosystems. The main findings and implications are summarized below:

1. **Difficulty in shifting away from anthropocentrism.** Although the possibility of adopting non-human personas was emphasized, none of the groups produced a

narrative from the point of view of a non-human actant. The results suggest cognitive and temporal barriers to sustaining genuinely relational perspectives. Even so, the interventionist solutions assigned responsibilities and intentionalities to non-human entities, indicating a movement toward recognizing distributed agency. It is recommended that future research investigate whether these representations become anthropomorphized, interpreted through the lens of correlationalism, in order to map the limits and possibilities of narrating the non-human beyond human centrality.

2. **Technologies as mediators of human agency.** It becomes necessary to develop mechanisms, such as new tools and facilitation-oriented discursive practices, that deepen reflection on the techno-material mediation of human agency, especially in contexts involving GenAI. Understanding how such systems intervene in ways of thinking, creating, and deciding is essential for guiding responsible uses and for making explicit the redistributions of agency involved in design practices.
3. **The political role of facilitators.** The incompleteness observed extends beyond time constraints and derives from tensions intrinsic to design. Facilitators must make opaque infrastructures explicit, problematize simplifications that portray users as purely rational or passive, resist impulses to stabilize systems and futures excessively, and maintain the process attentive to the noise, deviations, and resistances that escape analytical focus. At every stage, facilitation should foster situated and pluriversal readings that help avoid processes of *defuturing* (Blauvelt, 2020).
4. **Uncertainty as a methodological device and the collective construction of meaning.** Zones of uncertainty opened epistemological and aesthetic opportunities for negotiating meanings among multiple actors, human and non-human alike, repositioning *sensemaking* and *sensegiving* as simultaneous dynamics in contexts of risk and ambiguity (Dixon et al., 2017). Speculative practice proved to be more powerful when grounded in shared subjectivities, allowing futures to co-emerge with present conditions and with the different cosmologies at play.
5. **Contributions and limits of the Sociotechnical Board.** Mapping actants and relations broadened a relational and distributed understanding of action, making visible entities whose ontology and role were still uncertain. In contrast to ANT, which requires following actors and describing mediation chains, the Board enabled more open ontographic readings, strengthening analytical sensitivity to dynamics that tend to remain invisible. On the other hand, an excessively speculative perspective, insufficiently grounded in present descriptions, may over-relativize reality and produce scenarios that become distant from the analyzed context.
6. **Usefulness of the SEF cone and contributions of OOO.** The SEF cone is useful not only for projecting distant futures but also for guiding alternatives in the present and near future, informing provocative prototypes, usage narratives, critical user journeys, and impact simulations in IS. Two central elements of OOO emerged: flat ontology, which decentralizes the human, and the rejection of correlationalism, in which the future is treated as a partially accessible object whose qualities can be explored through situated speculation.

7. **Postphenomenology as an operative extension of Agential Realism.** Within the SEF, Postphenomenology appears as a complementary extension of Agential Realism by providing conceptual tools to analyze the specific effects of technical mediations on experience. This integration supports diffractive readings in which ethics and responsibility emerge from the material-discursive practices that constitute phenomena.
8. **Interference patterns and the diffractive thickening of analysis.** The power outage, the incorporation of questionnaires, the use of GenAI, and the evaluative instances of the research were recognized as interference patterns that enriched the diffractive reading. These events are not external to the study but constitutive of the entangled phenomenon in which both the workshop and the dissertation are situated, contributing to the incorporation of new materialities, voices, and apparatuses in the examination of the data.

In sum, this chapter aligns the SEF with a design practice attentive to more-than-human agencies, to incompleteness and uncertainty as heuristic strengths, and to the political role of facilitation in producing the conditions of possibility for desirable futures. By combining ontographic mappings, technologically mediated fabulations, and diffractive readings of interference patterns, the SEF offers pathways toward an expanded co-responsibility in the design of IS.

10. Conclusion

This dissertation begins with the recognition that technological design is often treated as a purely technical activity, lacking critical reflection on its ethical, social, and environmental implications. In this context, the aim of this work is to investigate how Entanglement Theories can be incorporated into Speculative Design to support more ethical, responsible, and post-anthropocentric design practices.

The investigation, integration, and operationalization of Entanglement Theories within the context of Speculative Design resulted in the creation of the SEF and a set of tools conceived to translate complex philosophical foundations into accessible and educational practices. Throughout this process, it was possible to advance significantly in understanding how these theories, when applied to design, expand awareness of non-human agency, the relational nature of reality, and the inseparability of ethics, technology, and the world.

Among the objectives achieved, the following stand out: (1) the coherent integration of four theoretical strands, namely ANT, Speculative Realism, Agential Realism, and Postphenomenology; (2) the proposition and instantiation of speculative projects based on a set of Speculative Design tools grounded in this model; and (3) the empirical evaluation of its application in participatory workshops.

These advances made it possible to identify concrete manifestations of post-anthropocentric principles in the participants' productions, such as the visibility of non-human actors, the recognition of technological mediations, and the development of narratives that problematize relations among humans, artifacts, and ecosystems. Nonetheless, the process revealed challenges. Time constraints and the cognitive effort required hindered the shift from a human-centered perspective to a more relational and material logic. No group, for instance, developed narratives from the perspective of a non-human actant, highlighting how deeply our thinking remains shaped by anthropocentric paradigms and how speculative practice can serve as a space for challenging these modes of thought.

10.1 Theoretical and Methodological Contributions

Entanglement Theories brought important contributions to Speculative Design. ANT offered a descriptive lens for examining relations, while Speculative Realism enabled the treatment of emergent phenomena, including those considered unreal, with ontological dignity. Agential Realism introduced the idea that ethics and knowledge co-emerge within material-discursive practices, and Postphenomenology added a refined perspective for understanding how artifacts mediate human experience and behavior.

By integrating concepts from ANT, it became possible to understand sociotechnical networks as dynamic ecosystems composed of multiple mediations in continuous transformation. Opening black boxes therefore becomes a political and epistemological

act that rejects simplistic explanations and seeks to reveal how different actants actively participate in the production of the real. Although ANT functions predominantly as a theoretical inspiration because of its demand for exhaustive analysis and description, which is impracticable in IS due to the accelerated nature of the field, its theoretical contributions were essential for this dissertation by reorienting the analytical gaze toward sociotechnical networks.

Complementarily, by integrating concepts from Speculative Realism into the field of Speculative Design, this dissertation proposes a shift in the traditional function of Speculative Design. Rather than serving only to create alternative realities or futures, Speculative Design becomes a way of understanding reality itself in its relational complexity. In this context, speculation ceases to be merely a projective imaginative exercise and assumes the role of an interpretive lens on the present, aiming to speculate about the mediations, tensions, and agencies that shape the sociotechnical world, especially when the descriptive plane of ANT is not capable of doing so. This perspective, still absent in the literature, constitutes an original contribution of this research, because it redefines the concept of the sociotechnical network by incorporating a speculative plane that entangles the empirical and the imaginary.

Furthermore, Speculative Realism within the SEF operates through two fundamental movements. The first involves recognizing the ontological dignity of all objects, including human, non-human, material, digital, institutional, or imaginary ones, as well as those that emerge from beliefs, affects, narratives, and public controversies. Phenomena such as conspiracy theories about climate manipulation, anti-vaccination movements, moral panics surrounding generative AI, controversies around 5G infrastructure, or digital mythologies circulating on social platforms exemplify objects that, even when epistemically fragile, possess full ontological existence. They organize practices, mobilize collectives, produce political effects, modulate behavior, and reconfigure sociotechnical ecosystems. To disregard them would be to obscure how such objects make a difference in the world. The second movement consists of understanding the future as an object in the OOO sense. The future is not treated as an abstract void or as a linear extension of the present, but as an entity with partially accessible qualities and others that are withdrawn, opaque, inaccessible, and not yet manifested. As with any object, the future appears to thought and design in fragmentary ways, revealing only some of its possibilities while others remain concealed and require disciplined speculation.

Postphenomenology and Agential Realism complement each other in the processes of intervention and evaluation. Traditionally used to analyze existing phenomena, here they were mobilized to design technologies whose effects unfold in the future, integrating themselves into the speculative process. This articulation allowed design to be understood as a practice that simultaneously describes, intervenes, and projects new possibilities for relations between humans and non-humans.

Agential Realism offers the contribution of co-emergence and diffractive analysis. From this perspective, knowledge production is understood as a performative process involving the researcher, the theories, the data, the thesis reviewers, and even the material infrastructure such as electrical power and technological apparatuses. All are intra-related and mutually constitutive. These intra-actions altered the course of the research itself,

giving rise to interference patterns that exceed the scope of the workshop and of traditional qualitative analyses. What emerges in practice is a deeply entangled phenomenon in which knowledge is continuously reconfigured by the relations that make it possible. As a phenomenon transformed by each observation, this work remains open, echoing the post-anthropocentric principle of incompleteness, according to which every attempt to map entanglement is, by nature, partial and provisional.

Finally, Speculative Design was used as a method for constructing the framework and its tools, guided by the three fundamental questions (where are we, where are we heading, where do we want to go). In this recursive relationship between method and product, co-emergence becomes evident. The SEF is developed at the same time that Speculative Design is mobilized as a critical, reflective, and creative practice within the framework.

10.2 Educational Contribution

The study by [Bendor e Lupetti \(2025\)](#) shows that although Speculative Design is widely recognized as a critical tool for understanding complex sociotechnical contexts, systematic, transferable, and accessible guidance on how to teach it is still lacking. Vague recommendations predominate, along with a tendency to present speculative design projects detached from the formative processes that give rise to them. This dissertation responds to this gap by structuring a pedagogical model that integrates post-anthropocentric principles, speculative tools, and a clear and applicable framework.

Translating this complexity into the educational domain was one of the greatest challenges of this research. Entanglement Theories are dense and resistant to simplification. For this reason, the post-anthropocentric principles were formulated as a conceptual filter capable of communicating central ideas, such as the notion that reality is relational but not totalizing, and that technology mediates our perception of the world. The results obtained in the workshop conducted at IHC 2024 indicate that the post-anthropocentric principles derived from Entanglement Theories softened the philosophical density without diminishing its depth.

The potential of the SEF and the tools developed extends beyond the technological context. They can be applied in broader educational settings and across diverse fields of knowledge. Faculty members from other higher education institutions have already begun using the tools and have expressed interest in understanding the SEF in greater depth. One example is a professor who employed the SEF tools to design futures in the field of Physical Education; another reported using the SEF in a regular undergraduate Information Systems course.

10.3 Technical Contribution

Beyond the SEF itself, the set of tools that composes it also represents an important technical contribution. With the exception of the Support Notebooks, which must be adapted to each specific workshop and function as a bridge between the different tools, the remaining tools were designed to be used independently, even outside the scope of the

SEF. Conversely, the SEF does not require the mandatory use of these tools and may be applied in conjunction with other methodological instruments, provided they are aligned with its three fundamental questions and with the post-anthropocentric principles that give the SEF its orientation and intentionality.

10.4 Practical Contribution

Although the SEF offers a significant contribution to technological design, its potential application extends beyond this field. The framework can be adapted to different contexts, such as public policy design, the promotion of behavior change, legislative development, smart city planning, screenplay creation, life-project development, and even the structuring of scientific research methodologies. Preliminary studies presented at the Brazilian Symposium on Information Systems (SBSI) indicate the feasibility of its application across multiple domains (Loutfi *et al.*, 2025). However, further progress is needed in its implementation within the software industry and other professional sectors in order to test and consolidate its potential for use in diverse practical contexts.

10.5 Threats to Validity

The main threat to internal validity arose from the interruption of the workshop due to a power outage, which prevented the planned focus group from taking place. This limitation initially reduced data triangulation and the presence of participants' voices. To mitigate this issue, a questionnaire based on the ARCS model was incorporated and the committee's reflexive assessment was included, recognizing the evaluative process itself as part of the entangled phenomenon.

Regarding external validity, the study was conducted in a single academic context, which limits its generalizability. To mitigate this limitation, triangulation with other scientific literature was carried out, including prior studies and publications by the author in which the SEF was applied in workshops conducted in different contexts and with distinct scopes. This comparison allowed patterns to be identified and strengthened the consistency of the findings.

With respect to construct validity, the tools created have not yet undergone a formal process of systematic validation. However, they were evaluated based on the extrapolations derived from the participants' productions and on the extent to which these productions reflected the Entanglement Theories within the post-anthropocentric principles that guide the SEF.

Finally, concerning conclusion validity, the interpretations produced emerge from the researcher's own analytical process, which may introduce biases into the final inferences. This threat was mitigated through the explicit acknowledgment of the researcher's implication in the co-constitution of the dissertation, assuming that knowledge emerges together with the phenomenon under investigation. The diffractive analysis adopted does not separate the researcher from the research but makes visible the interference patterns

that shaped the interpretations, thereby increasing transparency in the process. In this sense, threats to conclusion validity were reconfigured as part of the Entanglement Paradigm itself, in which conclusion is understood as ethical responsiveness and relational performativity between the researcher and the investigative practice.

10.6 Future Work

This research opens multiple possibilities for further development and expansion, both in theoretical and practical terms. Among the anticipated directions, the following stand out:

Refinement and expansion of the theoretical and methodological framework. The SEF may be extended through the incorporation of new theoretical currents that resonate with post-anthropocentric perspectives, including decolonial studies, intersectional feminist approaches, and critical design theories. Such an expansion aims to enrich the framework's capacity to analyze and reconfigure complex sociotechnical ecosystems.

Development and diversification of Speculative Design tools. New tools are currently being developed to support the SEF, including a chatbot created in collaboration with an undergraduate research student that integrates Haraway's cyborg concept (Haraway (2013a)) into Speculative Design to reflect on hybrid artifacts at the intersection of humans and technology. Additional solutions involving Generative AI are being conceived to enhance the framework's use, including prompt generators discussed in (Loutfi *et al.* (2025)), aligned with early reflections on the role of AI in design processes presented in (Loutfi *et al.* (2025a)).

Integration with other design initiatives. Ongoing studies aim to integrate the SEF with complementary approaches such as Socially Aware Design (SAwD) (Baranauskas *et al.* (2024)), in collaboration with an undergraduate research student. This integration seeks to strengthen the dialogue between methodologies that prioritize sociotechnical impact and responsibility in design.

Validation in diverse contexts and longitudinal studies. Future work involves testing the SEF and its tools in varied sectors such as industry, public services, local communities, and regulated environments, as well as conducting longitudinal studies to assess the impact of these applications on the development of more ethical, inclusive, and sociotechnically responsive design practices.

By pursuing these directions, it will be possible to expand the reach, applicability, and impact of the SEF, consolidating it as an adaptable approach for conceiving technologies within complex sociotechnical ecosystems.

Use of GenAI Tools in the Writing Process

The development of this dissertation was supported by Generative Artificial Intelligence (GenAI) tools, specifically the ChatGPT 5.1 model (OpenAI), employed in a controlled, transparent, and ethically responsible manner, in alignment with national and international guidelines on scientific integrity. The use of the tool did not replace intellectual authorship, critical analysis, theoretical interpretation, or the construction of the arguments presented. All conceptual, methodological, and analytical decisions are the sole responsibility of the author.

The use of GenAI occurred along three main fronts:

- **Orthographic and grammatical revision of text segments.** The tool was used to identify linguistic inconsistencies, improve textual fluency, and correct formal aspects of writing. No substantive rewriting of content was delegated to the AI, and all suggestions were evaluated, adjusted, or discarded in accordance with the academic rigor required.
- **Stylistic inspiration and reformulation.** In selected passages, GenAI was used to propose alternative paragraph structures, discursive transitions, and improvements in textual clarity. These suggestions served as stylistic inputs and never as automated authorial production. All conceptual content, including arguments, analyses, theoretical articulations, and interpretations, was produced by the researcher, with the AI contributing only linguistic possibilities that were subsequently reworked.
- **Translation of the dissertation into English.** The tool was used to support the translation of the dissertation into English. Each translation generated by the AI underwent careful human review to ensure terminological accuracy, conceptual fidelity, and alignment with the scholarly literature referenced in the research. As in the other cases, the AI functioned as an instrumental aid rather than an autonomous agent of scientific production.

The role of AI in this research was limited to refining textual form and assisting with translation, always under the direct supervision of the researcher and subject to deliberate decision-making. This practice aligns with current guidelines issued by major Brazilian academic and research institutions such as CAPES (Brazilian Federal Agency for Support and Evaluation of Graduate Education)¹, CNPq (National Council for Scientific and Technological Development)², and SBC (Brazilian Computer Society)³, as well as by international editorial committees. These bodies recognize the legitimacy of using GenAI when it is transparently reported, carefully supervised, and restricted to linguistic or stylistic support.

¹ CAPES: Coordenação de Aperfeiçoamento de Pessoal de Nível Superior

² CNPq: Conselho Nacional de Desenvolvimento Científico e Tecnológico

³ SBC: Sociedade Brasileira de Computação

References

- AITKEN, J.; BÖHME, T.; MCASH, E. Co-creation of societal benefits through human-centered design and management of dynamic capabilities in oyster farm communities. **Strategic Change**, Wiley Online Library, v. 34, n. 1, p. 93–101, 2025.
- AKMAL, H.; COULTON, P. The divination of things by things. In: **Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems**. [S.l.: s.n.], 2020. p. 1–12.
- AKMAL, H. A.; SANDOVAL, E. B. Proposing a post-anthropocentric hai through the perception of sentient entities as trans-objects. In: **Proceedings of the 10th International Conference on Human-Agent Interaction**. [S.l.: s.n.], 2022. p. 263–265.
- AKTER, S. *et al.* Advancing algorithmic bias management capabilities in ai-driven marketing analytics research. **Industrial Marketing Management**, Elsevier, v. 114, p. 243–261, 2023.
- ALEXANDER, P. M.; SILVIS, E. S. Actor-network theory in information systems research. University of Sheffield, 2014.
- ANDRADE, Y. *et al.* A descriptive and predictive analysis tool for criminal data: A case study from brazil. In: SPRINGER. **International Conference on Computational Science and Its Applications**. [S.l.], 2024. p. 151–169.
- ANTHIAS, P.; ASHER, K. Indigenous natures and the anthropocene: Racial capitalism, violent materialities, and the colonial politics of representation. **Antipode**, Wiley Online Library, 2024.
- ARANDA-MUNOZ, A.; YAMS, N. B.; CARLGREN, L. Co-experiential futuring: Where speculative design and arts meet futures studies. **Futures**, Elsevier, v. 166, p. 103549, 2025.
- ASSEMBLY, G. Resolution adopted by the general assembly on 11 september 2015. **New York: United Nations**, p. 14, 2015.
- BALANAY, R.; HALOG, A. A review of reductionist versus systems perspectives towards ‘doing the right strategies right’ for circular economy implementation. **Systems**, MDPI, v. 9, n. 2, p. 38, 2021.
- BALZ, A. G. Whitehead, descartes, and the bifurcation of nature. **The Journal of Philosophy**, v. 31, n. 11, p. 281–297, 1934.
- BARAD, K. **Meeting the universe halfway: Quantum physics and the entanglement of matter and meaning**. [S.l.]: duke university Press, 2007.
- BARAD, K. Diffracting diffraction: Cutting together-apart. **Parallax**, Taylor & Francis, v. 20, n. 3, p. 168–187, 2014.

BARANAUSKAS, M. C. C.; PEREIRA, R.; BONACIN, R. Socially aware systems design: a perspective towards technology-society coupling. **AIS Transactions on Human-Computer Interaction**, v. 16, n. 1, p. 80–109, 2024.

BARDZELL, J.; BARDZELL, S. What is "critical" about critical design? In: **Proceedings of the SIGCHI conference on human factors in computing systems**. [S.l.: s.n.], 2013. p. 3297–3306.

BARENDREGT, W. *et al.* The future of more-than-human design: A computing practice in crisis? In: **Adjunct Proceedings of the Sixth Decennial Aarhus Conference: Computing X Crisis**. [S.l.: s.n.], 2025. p. 1–4.

BECK, K. *et al.* Manifesto for agile software development. Snowbird, UT, 2001.

BEGO, C. R.; NWOKEJI, J. C.; TRYTTEN, D. A. Fie-toe guest editorial grand challenges in engineering and computing education: Beyond the pandemic. **IEEE Transactions on Education**, IEEE, v. 67, n. 3, p. 333–335, 2024.

BEKKER, T. *et al.* Challenges in teaching more-than-human perspectives in human-computer interaction education. In: **Proceedings of the 5th Annual Symposium on HCI Education**. [S.l.: s.n.], 2023. p. 55–58.

BENDOR, R.; LUPETTI, M. L. Teaching speculative design. **International Journal of Technology and Design Education**, Springer, v. 35, n. 1, p. 403–425, 2025.

BENJAMIN, J. J. *et al.* The entoptic field camera as metaphor-driven research-through-design with ai technologies. In: **Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems**. [S.l.: s.n.], 2023. p. 1–19.

BERG, M. Accumulating and coordinating: occasions for information technologies in medical work. **Computer Supported Cooperative Work (CSCW)**, Springer, v. 8, p. 373–401, 1999.

BERTMARK, A. M. Artefacts as pedagogy for futuring. In: **Proceedings of the Nineteenth International Conference on Tangible, Embedded, and Embodied Interaction**. [S.l.: s.n.], 2025. p. 1–9.

BIJKER, H.; HUGHES, T. P.; TREVOR, J. **Pinch, The Social Construction of Technological Systems**. [S.l.]: Cambridge MA: MIT Press, 1987.

BLAUVELT, A. Defuturing the image of the future. **Designs for Different Futures, Walker Art Center**, p. 41–47, 2019.

BLAUVELT, A. Defuturing the image of the future. **Designs for Different Futures, Walker Art Center**, p. 41–47, 2020. Accessed: 2025-06-02. Disponível em: <https://walkerart.org/magazine/defuturing-the-image-of-the-future>.

BLOK, V. **Philosophy of technology in the digital age: the datafication of the world, the homo virtualis, and the capacity of technological innovations to set the World free**. [S.l.]: Wageningen University & Research, 2023.

BOGOST, I. **Alien phenomenology, or, what it's like to be a thing**. [S.l.]: U of Minnesota Press, 2012.

BORNMAN, L.; DANIEL, H.-D. What do we know about the h index? **Journal of the American Society for Information Science and technology**, Wiley Online Library, v. 58, n. 9, p. 1381–1385, 2007.

BORNMAN, L.; MUTZ, R.; NEUHAUS, C.; DANIEL, H.-D. Citation counts for research evaluation: standards of good practice for analyzing bibliometric data and presenting and interpreting results. **Ethics in science and environmental politics**, v. 8, n. 1, p. 93–102, 2008.

BRAY, K. E.; HARRINGTON, C.; PARKER, A. G.; DIAKHATE, N.; ROBERTS, J. Radical futures: Supporting community-led design engagements through an afrofuturist speculative design toolkit. In: **Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems**. [S.l.: s.n.], 2022. p. 1–13.

BROCKE, J. V.; STEIN, A.; HOFMANN, S.; TUMBAS, S. **Grand societal challenges in information systems research and education: Ideas from the ERCIS virtual seminar series**. [S.l.]: Springer, 2015.

BUSBOOM, J. B. The futures of hybrid work-participatory futuring in practice. In: **Companion Proceedings of the 2023 ACM International Conference on Supporting Group Work**. [S.l.: s.n.], 2023. p. 48–50.

CALDERWOOD, A. Designing for posthuman critical literacy. In: **Proceedings of the Third Workshop on Intelligent and Interactive Writing Assistants**. [S.l.: s.n.], 2024. p. 65–68.

CALLON, M. Some elements of a sociology of translation: domestication of the scallops and the fishermen of st brieuc bay. **The sociological review**, SAGE Publications Sage UK: London, England, v. 32, n. 1_suppl, p. 196–233, 1984.

CANDY, S.; DUNAGAN, J. Designing an experiential scenario: The people who vanished. **Futures**, Elsevier, v. 86, p. 136–153, 2017.

CASSELLS, C. J. **Reassembling the monad: the intellectual genealogy of an actant rhizome ontology**. Tese (Doutorado) — University of Glasgow, 2019.

CELLARD, L. Algorithms as figures: Towards a post-digital ethnography of algorithmic contexts. **New Media & Society**, SAGE Publications Sage UK: London, England, v. 24, n. 4, p. 982–1000, 2022.

CHAN, J. Y.-C.; NAGASHIMA, T.; CLOSSER, A. H. Participatory design for cognitive science: Examples from the learning sciences and human- computer interaction. **Cognitive Science**, Wiley Online Library, v. 47, n. 10, p. e13365, 2023.

CHEN, Y.; PSCHETZ, L. Microbial revolt: Redefining biolab tools and practices for more-than-human care ecologies. In: **Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems**. [S.l.: s.n.], 2024. p. 1–16.

CHEON, E. Powerful futures: How a big tech company envisions humans and technologies in the workplace of the future. **Proceedings of the ACM on Human-Computer Interaction**, ACM New York, NY, USA, v. 7, n. CSCW2, p. 1–35, 2023.

CHIVUKULA, S. S.; LI, Z.; PIVONKA, A. C.; CHEN, J.; GRAY, C. M. Surveying the landscape of ethics-focused design methods. **arXiv preprint arXiv:2102.08909**, 2021.

CIRIELLO, R. F.; RICHTER, A.; MATHIASSEN, L. Emergence of creativity in is development teams: A socio-technical systems perspective. **International Journal of Information Management**, Elsevier, v. 74, p. 102698, 2024.

CLEMENSEN, J. *et al.* Participatory design in telehealth research: practical case examples. **Journal of Telemedicine and Telecare**, SAGE Publications Sage UK: London, England, v. 31, n. 8, p. 1193–1200, 2025.

CONNOLLY, R. Why computing belongs within the social sciences. **Communications of the ACM**, Association for Computing Machinery, v. 63, n. 8, p. 54–59, August 2020. Disponível em: <https://cacm.acm.org/magazines/2020/8/246877-why-computing-belongs-within-the-social-sciences/fulltext>.

COULTON, P.; LINDLEY, J. G. More-than human centred design: Considering other things. **The Design Journal**, Taylor & Francis, v. 22, n. 4, p. 463–481, 2019.

COULTON, P. *et al.* Designing prosocial more-than-human rhetoric within experiential futures. In: **Proceedings of the 27th International Academic Mindtrek Conference**. [S.l.: s.n.], 2024. p. 36–45.

CRESSWELL, K. M.; WORTH, A.; SHEIKH, A. Actor-network theory and its role in understanding the implementation of information technology developments in healthcare. **BMC medical informatics and decision making**, Springer, v. 10, p. 1–11, 2010.

CRUZ, S. *et al.* From insight to foresight: The transformative potential of the futures triangle. **World Futures Review**, SAGE Publications Sage CA: Los Angeles, CA, v. 15, n. 2-4, p. 156–169, 2023.

DABAGHI, K. Beyond design thinking and into speculative futures in legal design. In: LOCKTON, D. *et al.* (Ed.). **DRS2022: Bilbao, 25 June – 3 July**. Bilbao, Spain: Design Research Society, 2022. Disponível em: <https://dl.designresearchsociety.org/drs-conference-papers/>.

DEDEOĞLU, Ç.; ZAMPAKI, N. Posthumanism for sustainability: A scoping review. **Journal of Posthumanism**, v. 3, n. 1, p. 33–57, 2023.

DIJKSTRA, E. W. **A Discipline of Programming**. [S.l.]: Prentice Hall, Inc, 1976.

DILLAHUNT, T. R.; LU, A. J.; VELAZQUEZ, J. Eliciting alternative economic futures with working-class detroiters: Centering afrofuturism in speculative design. In: **Proceedings of the 2023 ACM Designing Interactive Systems Conference**. [S.l.: s.n.], 2023. p. 957–977.

DIXON, D. P.; WEEKS, M.; JR, R. B.; PERELLI, S. Making sense when it matters most: An exploratory study of leadership in extremis. **Journal of Leadership & Organizational Studies**, Sage Publications Sage CA: Los Angeles, CA, v. 24, n. 3, p. 294–317, 2017.

DOOLIN, B.; LOWE, A. To reveal is to critique: actor–network theory and critical information systems research. **Journal of information technology**, Springer, v. 17, n. 2, p. 69–78, 2002.

DÖRRENBÄCHER, J.; RINGFORT-FELNER, R.; HASSENZAHN, M. The intricacies of social robots: secondary analysis of fictional documentaries to explore the benefits and challenges of robots in complex social settings. In: **Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems**. [S.l.: s.n.], 2023. p. 1–13.

DUBOC, L.; MCCORD, C.; BECKER, C.; AHMED, S. I. Critical requirements engineering in practice. **IEEE Software**, IEEE, v. 37, n. 1, p. 17–24, 2019.

DUNBAR, M.; SPEED, C. Data sets for regenerative futures: Cultivating relational ontologies. In: **Proceedings of the Halfway to the Future Symposium**. [S.l.: s.n.], 2024. p. 1–4.

DUNNE, A.; RABY, F. **Speculative Everything, With a new preface by the authors: Design, Fiction, and Social Dreaming**. [S.l.]: MIT press, 2024.

ECKHARDT, J.; VOGELSANG, A.; FERNÁNDEZ, D. M. Are" non-functional" requirements really non-functional? an investigation of non-functional requirements in practice. In: **Proceedings of the 38th international conference on software engineering**. [S.l.: s.n.], 2016. p. 832–842.

EDWARDS, F.; PETTERSEN, I. N. Speculative design for envisioning more-than-human futures in desirable counter-cities. **Cities**, Elsevier, v. 142, p. 104553, 2023.

ELSDEN, C.; DISLEY, M.; SPEED, C. Designing with transactional data: Ftml and money/data laundering. In: **Proceedings of the 2024 ACM Designing Interactive Systems Conference**. [S.l.: s.n.], 2024. p. 301–313.

ELSDEN, C. *et al.* Designing futures of money and fintech. In: **Companion Publication of the 2020 ACM Designing Interactive Systems Conference**. [S.l.: s.n.], 2020. p. 429–432.

ELSDEN, C.; GLOERICH, I.; NISSEN, B. Designing new financial transactions: Theories, case studies, methods, practice and futures. In: LOCKTON, D. *et al.* (Ed.). **DRS2022: Bilbao, 25 June – 3 July**. Bilbao, Spain: Design Research Society, 2022. Disponível em: <https://dl.designresearchsociety.org/drs-conference-papers/>.

ENCINAS, E.; DURRANT, A. C.; MITCHELL, R.; BLYTHE, M. Metaprobes, metaphysical workshops and sketchy philosophy. In: **Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems**. [S.l.: s.n.], 2020. p. 1–13.

ENCINAS, E.; HELGASON, I.; AUGER, J.; MITROVIĆ, I.; HANNA, J. Speculative designs in educational settings: Tension-patterns from a (mostly) european perspective. In: HOLMLID, S. *et al.* (Ed.). **Nordes 2023: This Space Intentionally Left Blank**. Norrköping, Sweden: Linköping University, 2023. Disponível em: <https://doi.org/10.21606/nordes.2023.98>.

FARIAS, P. G.; BENDOR, R.; EEKELEN, B. F. V. Social dreaming together: A critical exploration of participatory speculative design. In: **Proceedings of the Participatory Design Conference 2022-Volume 2**. [S.l.: s.n.], 2022. p. 147–154.

FEENBERG, A. Critical theory of technology: An overview. **Information technology in librarianship: New critical approaches**, Libraries Unlimited Westport, CT, p. 31–46, 2008.

FERRANDO, F. The party of the anthropocene: Post-humanism, environmentalism and the post-anthropocentric paradigm shift. **Rel.: Beyond Anthropocentrism**, HeinOnline, v. 4, p. 159, 2016.

FORLANO, L. E.; HALPERN, M. K. Speculative histories, just futures: From counterfactual artifacts to counterfactual actions. **ACM Transactions on Computer-Human Interaction**, ACM New York, NY, v. 30, n. 2, p. 1–37, 2023.

FOX, N. J.; ALLDRED, P. New materialism. **The SAGE encyclopedia of research methods**, Sage, p. 1–16, 2019.

FRAUENBERGER, C. Entanglement hci the next wave? **ACM Transactions on Computer-Human Interaction (TOCHI)**, ACM New York, NY, USA, v. 27, n. 1, p. 1–27, 2019.

FU, Z.; ZHU, L. Envisioning the future scenario through design fiction generating toolkits. In: SPRINGER. **Cross-Cultural Design. User Experience of Products, Services, and Intelligent Environments: 12th International Conference, CCD 2020, Held as Part of the 22nd HCI International Conference, HCII 2020, Copenhagen, Denmark, July 19–24, 2020, Proceedings, Part I 22**. [S.l.], 2020. p. 46–59.

GALE, N. K.; HEATH, G.; CAMERON, E.; RASHID, S.; REDWOOD, S. Using the framework method for the analysis of qualitative data in multi-disciplinary health research. **BMC medical research methodology**, Springer, v. 13, n. 1, p. 117, 2013.

GAO, J.; YIN, Y.; MYERS, K. R.; LAKHANI, K. R.; WANG, D. Potentially long-lasting effects of the pandemic on scientists. **Nature communications**, Nature Publishing Group UK London, v. 12, n. 1, p. 6188, 2021.

GERSHENSON, C. The implications of interactions for science and philosophy. **Foundations of Science**, Springer, v. 18, n. 4, p. 781–790, 2013.

GIACCARDI, E.; REDSTRÖM, J.; NICENBOIM, I. **The making (s) of more-than-human design: introduction to the special issue on more-than-human design and HCI**. [S.l.]: Taylor & Francis, 2025. 1–16 p.

GRAHAM, S. The end of geography or the explosion of place? conceptualizing space, place and information technology. **Progress in human geography**, sage Publications Sage CA: Thousand Oaks, CA, v. 22, n. 2, p. 165–185, 1998.

GÜNEŞ, S.; GÖRGÜN, Ç. E. The ethical dimension of the persona concept. **Gazi University Journal of Science Part B: Art Humanities Design and Planning**, Gazi University, v. 10, n. 2, p. 147–158, 2022.

GUPTA, B.; DHAWAN, S.; AHMED, K. M.; MAMDAPUR, G. M. Global research on covid-19 disease: a scientific assessment of publications during 2020-21. 2021.

HAI-BOLOURI, A.; CONBOY, K.; GREGOR, S. Research perspectives: An encompassing framework for conceptualizing space in information systems: Philosophical perspectives, themes, and concepts. **Journal of the Association for Information Systems**, v. 25, n. 2, p. 407–441, 2024.

HANSEN, T. **Thinking in Systems: A Sociotechnical Approach to DevOps**. 2023. Acesso em 01-jun-2025. Disponível em: <https://thenewstack.io/thinking-in-systems-a-sociotechnical-approach-to-devops/>.

HARAWAY, D. A cyborg manifesto: Science, technology, and socialist-feminism in the late twentieth century. In: **The transgender studies reader**. [S.l.]: Routledge, 2013. p. 103–118.

HARAWAY, D. Situated knowledges: The science question in feminism and the privilege of partial perspective 1. In: **Women, science, and technology**. [S.l.]: Routledge, 2013. p. 455–472.

HARAWAY, D. Staying with the trouble: Making kin in the chthulucene. **Duke UP**, 2016.

HARAWAY, D. J. Sf: Science fiction, speculative fabulation, string figures, so far. Fembot Collective, 2013.

HARMAN, G. **The Quadruple Object**. [S.l.]: Zero Books, 2011. ISBN 9781846947001.

HARMAN, G. **Object-oriented ontology: A new theory of everything**. [S.l.]: Penguin UK, 2018.

HARTY, C. Implementing innovation in construction: contexts, relative boundedness and actor-network theory. **Construction management and economics**, Taylor & Francis, v. 26, n. 10, p. 1029–1041, 2008.

HASSAN, N. R.; LOEBBECKE, C. Engaging scientometrics in information systems: combining the quantitative and qualitative. In: **Proceedings of the Thirty First International Conference on Information Systems (ICIS 2010)**. St. Louis, Missouri, USA: Association for Information Systems, 2010. Disponível em: https://aisel.aisnet.org/icis2010_submissions/234.

HAUSER, S.; OOGJES, D.; WAKKARY, R.; VERBEEK, P.-P. An annotated portfolio on doing postphenomenology through research products. In: **Proceedings of the 2018 designing interactive systems conference**. [S.l.: s.n.], 2018. p. 459–471.

HELGASON, I. *et al.* **Speculative Design in Education: Mapping the Landscape**. 2021. 'The accepted papers will be published digitally with an ISBN before the Conference.' - <https://cumulusroma2020.org/faq/>. Disponível em: <http://researchrepository.napier.ac.uk/Output/2748285>.

HENRY, J. V. Theorizing 'the gap' twenty years later: Global development, design, and speculative ethics in edtech research. **Postdigital Science and Education**, Springer, v. 6, n. 1, p. 231–258, 2024.

HESPAHOL, L. Human-computer intra-action: a relational approach to digital media and technologies. **Frontiers in Computer Science**, Frontiers Media SA, v. 5, p. 1083800, 2023.

HIND, S.; LAMMES, S. Digital mapping as double-tap: Cartographic modes, calculations and failures. **Global Discourse**, Bristol University Press, v. 6, n. 1-2, p. 79–97, 2016.

HINES, A.; BISHOP, P. J.; SLAUGHTER, R. A. **Thinking about the future: Guidelines for strategic foresight**. [S.l.]: Social Technologies Washington, DC, 2006.

HOHENDANNER, M. *et al.* Metaverse perspectives from japan: A participatory speculative design case study. **Proceedings of the ACM on Human-Computer Interaction**, ACM New York, NY, USA, v. 8, n. CSCW2, p. 1–51, 2024.

HOLLY, E. How a torrent of covid science changed research publishing. **Nature**, v. 588, p. 553, 2020.

HOMEWOOD, S.; HEDEMYR, M.; RANTEN, M. F.; KOZEL, S. Tracing conceptions of the body in hci: From user to more-than-human. In: **Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems**. [S.l.: s.n.], 2021. p. 1–12.

HYRYNSALMI, S. M. *et al.* Making software development more diverse and inclusive: Key themes, challenges, and future directions. **ACM Transactions on Software Engineering and Methodology**, ACM New York, NY, v. 34, n. 5, p. 1–23, 2025.

IHDE, D. **Technology and the lifeworld: From garden to earth**. [S.l.]: Indiana University Press, 1990.

IHDE, D. **Postphenomenology: Essays in the postmodern context**. [S.l.]: Northwestern University Press, 1995.

JENSEN, R. H.; NILSSON, E. M.; HANSEN, A.-M.; YOO, D.; ERIKSSON, E. Provocations and more-than-human perspectives in human–computer interaction. **Interacting with Computers**, Oxford University Press, p. iwaf020, 2025.

JOHANNESSEN, L. K.; KEITSCH, M. M.; PETTERSEN, I. N. Speculative and critical design—features, methods, and practices. In: CAMBRIDGE UNIVERSITY PRESS. **Proceedings of the design society: international conference on engineering design**. [S.l.], 2019. v. 1, n. 1, p. 1623–1632.

JONES, M. L. How we became instrumentalists (again) data positivism since world war ii. **Historical Studies in the Natural Sciences**, University of California Press, v. 48, n. 5, p. 673–684, 2018.

JORDAN, T. Hacking and power: Social and technological determinism in the digital age. **First Monday**, 2009.

JR, R. J. B.; LYYTINEN, K. The limits to language in doing systems design. **European Journal of Information Systems**, Taylor & Francis, v. 26, n. 3, p. 248–259, 2017.

JUDGE, R.; ELAHI, S. Beyond the boundaries: characterising situational uncertainty in complex systems. **Engineering X**, 2022.

JUNIOR, D. P. da S. *et al.* Grandihc-br 2025-2035-gc1: New theoretical and methodological approaches in hci. In: **Proceedings of the XXIII Brazilian Symposium on Human Factors in Computing Systems**. [S.l.: s.n.], 2024. p. 1–31.

- KANT, I. **Crítica da razão pura**. [S.l.]: Edipro, 2020.
- KARWOWSKI, W. *et al.* Grand challenges in industrial and systems engineering. **International Journal of Production Research**, Taylor & Francis, v. 63, n. 4, p. 1538–1583, 2025.
- KEERE, K. D.; MILAN, S. The value of crypto? sociotechnical imaginaries on cryptocurrency in youtube content. **Socio-Economic Review**, Oxford University Press, p. mwae081, 2025.
- KELLER, J. M. Development and use of the arcs model of instructional design. **Journal of instructional development**, Springer, v. 10, n. 3, p. 2–10, 1987.
- KELTY, C. M. An inquiry into the modes of existence of latour. **Science, Technology, & Human Values**, SAGE Publications Sage CA: Los Angeles, CA, v. 48, n. 5, p. 999–1017, 2023.
- KEY, C.; GATEHOUSE, C.; TAYLOR, N. Feminist care in the anthropocene: Packing and unpacking tensions in posthumanist hci. In: **Proceedings of the 2022 ACM Designing Interactive Systems Conference**. [S.l.: s.n.], 2022. p. 677–692.
- KIMURA, R.; NAKAJIMA, T. On designing affordances of ambient digital artifacts through the lens of postphenomenology and sociomateriality. In: **Proceedings of the 25th International Academic Mindtrek Conference**. [S.l.: s.n.], 2022. p. 354–358.
- KIMURA, R.; NAKAJIMA, T. Designing innovative digital platforms from both human and nonhuman perspectives. **Multimedia Tools and Applications**, Springer, v. 82, n. 26, p. 39961–40008, 2023.
- KITCHENHAM, B. A.; MADEYSKI, L.; BUDGEN, D. SEGRESS: Software Engineering Guidelines for REporting Secondary Studies. **IEEE Transactions on Software Engineering**, v. 49, n. 3, p. 1273–1298, 2023.
- KLINGBERG, S.; STALMEIJER, R. E.; VARPIO, L. Using framework analysis methods for qualitative research: Amee guide no. 164. **Medical Teacher**, Taylor & Francis, v. 46, n. 5, p. 603–610, 2024.
- KONG, B. *et al.* Neuromancer workshop: Towards designing experiential entanglement with science fiction. In: **Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems**. [S.l.: s.n.], 2021. p. 1–17.
- KRAKOWSKI, S. Human-ai agency in the age of generative ai. **Information and Organization**, Elsevier, v. 35, n. 1, p. 100560, 2025.
- KRUGER, J. Nature, culture, ai and the common good—considering ai’s place in bruno latour’s politics of nature. In: SPRINGER. **Southern African Conference for Artificial Intelligence Research**. [S.l.], 2021. p. 21–33.
- KUHN, T. How to evaluate controlled natural languages. **arXiv preprint arXiv:0907.1251**, 2009.
- LATOUR, B. **Science in action: How to follow scientists and engineers through society**. [S.l.]: Harvard university press, 1987.

- LATOUR, B. **The pasteurization of France**. [S.l.]: Harvard University Press, 1993.
- LATOUR, B. **Aramis, or the Love of Technology**. [S.l.]: Harvard University Press, 1996.
- LATOUR, B. Social theory and the study of computerized work sites. In: **Information technology and changes in organizational work**. [S.l.]: Springer, 1996. p. 295–307.
- LATOUR, B. **Reassembling the social: An introduction to actor-network-theory**. [S.l.]: Oxford university press, 2005.
- LATOUR, B. What is given in experience? a review of isabelle stengers' *penser avec whitehead*. **Boundary 2**, v. 32, n. 1, p. 222–237, 2005.
- LATOUR, B. **We have never been modern**. [S.l.]: Harvard university press, 2012.
- LATOUR, B. **An inquiry into modes of existence**. [S.l.]: Harvard University Press, 2013.
- LATOUR, B. **Down to earth: Politics in the new climatic regime**. [S.l.]: John Wiley & Sons, 2018.
- LATOUR, B.; HERMANT, E. **Paris: invisible city**. [S.l.]: Bruno Latour Paris, 2006.
- LAZAR, A.; JELEN, B.; PRADHAN, A.; SIEK, K. A. Adopting diffractive reading to advance hci research: A case study on technology for aging. **ACM Transactions on Computer-Human Interaction (TOCHI)**, ACM New York, NY, v. 28, n. 5, p. 1–29, 2021.
- LEITONIENE, S.; KUNDELIENE, K. Sustainability reporting: the environmental impacts of digitalization. In: IEEE. **2021 IEEE International Conference on Technology and Entrepreneurship (ICTE)**. [S.l.], 2021. p. 1–6.
- LEMOS, A. Comunicação das coisas: Teoria ator-rede e cibercultura. são paulo: Annablume, 2013. **Mídia Locativa e Territórios Informacionais**. Curitiba: E-Compós, 2007.
- LEVY, S. **In the plex: How Google thinks, works, and shapes our lives**. [S.l.]: Simon & Schuster, 2021.
- LI, K.; KELLER, J. M. Use of the arcs model in education: A literature review. **Computers & Education**, Elsevier, v. 122, p. 54–62, 2018.
- LIGHT, A. More-than-human participatory approaches for design: Method and function in making relations. In: **Proceedings of the Participatory Design Conference 2024: Exploratory Papers and Workshops-Volume 2**. [S.l.: s.n.], 2024. p. 1–6.
- LIN, K. Do abstractions have politics? toward a more critical algorithm analysis. In: IEEE. **2021 Conference on Research in Equitable and Sustained Participation in Engineering, Computing, and Technology (RESPECT)**. [S.l.], 2021. p. 1–5.
- LINDLEY, J. Crypto heater: A design fiction. In: **Proceedings of the 2015 ACM SIGCHI Conference on Creativity and Cognition**. [S.l.: s.n.], 2015. p. 355–356.

- LOUTFI, M. S.; ALBUQUERQUE, B. V. L. d.; XAVIER, C. S.; SIQUEIRA, S. W. M. Design especulativo: Construindo pontes entre tecnologia, Ética e inclusão social. In: CORRÊA, C.; DELABRIDA, S. (Ed.). **Minicursos do IHC 2024: Fundamentos e Práticas para Experiências Digitais Acessíveis, Inclusivas e Eticamente Responsáveis**. Porto Alegre: Sociedade Brasileira de Computação, 2024, (Perspectivas e Práticas Contemporâneas em IHC). p. 18–38.
- LOUTFI, M. S.; CIDRINI, C. H. C.; ARAUJO, R. M. de; SIQUEIRA, S. W. M. Explorando futuros tecnológicos em contexto: Um relato de experiência com design especulativo e ia generativa na graduação. In: SBC. **Simpósio Brasileiro sobre Fatores Humanos em Sistemas Computacionais (IHC)**. [S.l.], 2025. p. 238–258.
- LOUTFI, M. S.; RIBEIRO, T. M. de R.; RAMOS, F. da F.; SIQUEIRA, S. W. M. Teorias do emaranhado e design especulativo na computação: Mapeamento sistemático de literatura e implicações para a interação humano-computador. In: SBC. **Simpósio Brasileiro sobre Fatores Humanos em Sistemas Computacionais (IHC)**. [S.l.], 2025. p. 1323–1349.
- LOUTFI, M. S.; SIQUEIRA, S. W. M. Speculative design in a graduate program in informatics: Students perception and practical application: A novel approach for supporting information systems education. In: **Proceedings of the 20th Brazilian Symposium on Information Systems**. [S.l.: s.n.], 2024. p. 1–10.
- LOUTFI, M. S.; TIBAU, M.; GIMENEZ, P. J.; SIQUEIRA, S. W. M. Students' perceptions of speculative design with generative ai in creating futuristic narratives: An interdisciplinary study with undergraduate students from diverse fields. In: SBC. **Simpósio Brasileiro de Sistemas de Informação (SBSI)**. [S.l.], 2025. p. 585–594.
- LOUTFI, M. S.; XAVIER, C. S.; ALBUQUERQUE, B. V. L. d.; MATSUI, S. W. Cartas de mediação tecnológica. In: MELO, T. A. C. A. M. (Ed.). **Práticas de IHC em Sala de Aula: ações extensionistas em pauta**. Rio de Janeiro, BR: SBC – Sociedade Brasileira de Computação, 2024. p. 7–12.
- MACKENZIE, D.; WAJCMAN, J. **The social shaping of technology**. [S.l.]: Open University, 1999.
- MALIK, M.; MALIK, M. M. Critical technical awakenings. **Journal of Social Computing**, TUP, v. 2, n. 4, p. 365–384, 2021.
- MALPASS, M. **Critical design in context: History, theory, and practice**. [S.l.]: Bloomsbury Publishing, 2019.
- MANDIROLA, S. Four alternative currencies and their worlds. **Economic Anthropology**, Wiley Online Library, v. 12, n. 1, p. e12348, 2025.
- MCGUIRE, S.; SCHULTZ, E.; AYOOOLA, B.; RALPH, P. Sustainability is stratified: Toward a better theory of sustainable software engineering. In: IEEE. **2023 IEEE/ACM 45th International Conference on Software Engineering (ICSE)**. [S.l.], 2023. p. 1996–2008.
- MEILLASSOUX, Q. After finitude: An essay on the necessity of contingency, translated by r. Brassier, London: Continuum. First published in, 2006.

- MELLAMPHY, N. B.; VANGEEST, J. Human, all too human? anthropocene narratives, posthumanisms, and the problem of “post-anthropocentrism”. **The Anthropocene Review**, SAGE Publications Sage UK: London, England, v. 11, n. 3, p. 599–613, 2024.
- MELUSO, J.; CASARI, A.; MCLAUGHLIN, K.; TRUJILLO, M. Z. Invisible labor in open source software ecosystems. **Proceedings of the ACM on Human-Computer Interaction**, ACM New York, NY, USA, v. 9, n. 7, p. 1–32, 2025.
- MEYERSON, B. Clearing up correlationism: Goldschmidt, meillassoux, and the problem of finitude. **Philosophy Today**, 2023.
- MILOJEVIĆ, I.; INAYATULLAH, S. Narrative foresight. **Futures**, Elsevier, v. 73, p. 151–162, 2015.
- MITROVIĆ, I.; AUGER, J.; HANNA, J.; HELGASON, I. **Beyond speculative design: past–present–future**. [S.l.]: University of Split, 2021.
- MORALES-NAVARRO, L.; KAFAI, Y. B. Conceptualizing approaches to critical computing education: Inquiry, design, and reimagination. In: **Past, present and future of computing education research: A global perspective**. [S.l.]: Springer, 2023. p. 521–538.
- MOZUNI, M.; JONAS, W. An introduction to the morphological delphi method for design: A tool for future-oriented design research. **She Ji: The Journal of Design, Economics, and Innovation**, Elsevier, v. 3, n. 4, p. 303–318, 2017.
- MWENYA, J. K.; BROWN, I. Actor-network theory in is research: critique on application of the principle of generalized symmetry. **Proceedings of the South African Institute of Computer Scientists and Information Technologists**, p. 1–10, 2017.
- NICENBOIM, I. *et al.* More-than-human design in practice. In: DESIGN RESEARCH SOCIETY. **Design Research Society, DRS 2024: Resistance, Recovery, Reflection, Reimagination**. [S.l.], 2024.
- NIELSEN, J. Ten usability heuristics. <http://www.nngroup.com/articles/ten-usability-heuristics/>(acc-essed ... , 2005.
- NIELSEN, J.; MOLICH, R. Heuristic evaluation of user interfaces. In: **Proceedings of the SIGCHI conference on Human factors in computing systems**. [S.l.: s.n.], 1990. p. 249–256.
- NOBLE, H.; MITCHELL, G. What is grounded theory? **Evidence-based nursing**, Royal College of Nursing, v. 19, n. 2, p. 34–35, 2016.
- NOBLE, S. U. Algorithms of oppression: How search engines reinforce racism. In: **Algorithms of oppression**. [S.l.]: New York university press, 2018.
- ÖNGÖREN, H. Critique of transhumanism, artificial intelligence, and digital society in terms of social values. **Journal of Interdisciplinary Education: Theory and Practice**, Eğitim Araştırmaları ve Yayınları Derneği (ERPA), v. 6, n. 1, p. 51–65, 2024.
- OOGJES, D.; WAKKARY, R. Videos of things: Speculating on, anticipating and synthesizing technological mediations. In: **Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems**. [S.l.: s.n.], 2017. p. 4489–4500.

ØSTERLUND, C.; CROWSTON, K.; JACKSON, C. Building an apparatus: Refractive, reflective, and diffractive readings of trace data. **Journal of the Association for Information Systems**, v. 21, n. 1, p. 10, 2020.

OULASVIRTA, A.; HORNBÆK, K. Counterfactual thinking: What theories do in design. **International Journal of Human–Computer Interaction**, Taylor & Francis, v. 38, n. 1, p. 78–92, 2022.

ÖZTÜRK, O.; KOCAMAN, R.; KANBACH, D. K. How to design bibliometric research: an overview and a framework proposal. **Review of managerial science**, Springer, p. 1–29, 2024.

PAGE, M. J. *et al.* The prisma 2020 statement: an updated guideline for reporting systematic reviews. **Systematic reviews**, BioMed Central, v. 10, n. 1, p. 1–11, 2021.

PARK, Y. S.; KONGE, L.; JR, A. R. A. The positivism paradigm of research. **Academic medicine**, LWW, v. 95, n. 5, p. 690–694, 2020.

PARRA, H.; CRUZ, L.; AMIEL, T.; MACHADO, J. Infraestruturas, economia e política informacional: o caso do google suite for education. **Mediações-Revista de Ciências Sociais**, p. 63–99, 2018.

PASA, B.; SINNI, G. Democracy in outer space: Speculative design for future citizenship. In: **For Nature/With Nature: New Sustainable Design Scenarios**. [S.l.]: Springer, 2024. p. 965–980.

PENTLAND, B. T.; FELDMAN, M. S. Narrative networks: Patterns of technology and organization. **Organization science**, INFORMS, v. 18, n. 5, p. 781–795, 2007.

PERRIN, A. J.; DORRELL, R. G. Protists and protistology in the anthropocene: challenges for a climate and ecological crisis. **BMC biology**, Springer, v. 22, n. 1, p. 279, 2024.

PETRONIO, R. Introdução à teoria gerativa—parte 1:: Conhecimento, cosmologia e emergência a partir da obra de david deutsch. **TECCOGS: Revista Digital de Tecnologias Cognitivas**, v. 1, n. 27, 2023.

PRABAKAR, S. *et al.* Strategic integration for future selection-lstm stock prediction algorithm based on the internet of things (iot). In: IEEE. **2024 1st International Conference on Advanced Computing and Emerging Technologies (ACET)**. [S.l.], 2024. p. 1–6.

RAFAEL, S.; SILVA, B.; ANJOS, H.; MEINTJES, L.; TAVARES, P. Data surveillance in capitalism society: The globule app, a speculative design to control the algorithm. In: **Proceedings of the 2023 ACM International Conference on Interactive Media Experiences Workshops**. [S.l.: s.n.], 2023. p. 27–31.

RAJCIC, N.; MCCORMACK, J. Message ritual: a posthuman account of living with lamp. In: **Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems**. [S.l.: s.n.], 2023. p. 1–16.

RANDELL, B. The 1968/69 nato software engineering reports. **History of software engineering**, v. 37, 1996.

RIEDER, A.; CHAKRABORTY, S.; GOYAL, S.; BERNDT, D. J. A critical realist approach to agent-based modeling: Unlocking prediction in non-positivist paradigms. **Journal of Information Technology**, SAGE Publications Sage UK: London, England, p. 02683962241280657, 2024.

RITCHEY, T. Wicked problems. **Acta morphologica generalis**, v. 2, n. 1, 2013.

ROSENBERGER, R.; VERBEEK, P.-P. A field guide to postphenomenology. **Postphenomenological investigations: Essays on human-technology relations**, Lexington Books Lanham, MD, p. 9–41, 2015.

ROSSI, A.; CHATELLIER, R.; LEUCCI, S.; DUCATO, R.; HARY, E. What if data protection embraced foresight and speculative design? **DRS2022 Bilbao**, DRS Digital Library, 2022.

ROZENDAAL, M. C.; VROON, J.; BLEEKER, M. Enacting human–robot encounters with theater professionals on a mixed reality stage. **ACM Transactions on Human-Robot Interaction**, ACM New York, NY, v. 14, n. 1, p. 1–25, 2024.

SAMJI, S.; KAPOOR, M. Funda wande through the lens of pdia: Improving educational outcomes via flexibility, iteration, and learning. 2022.

SANDERS, A. K. *et al.* World economic and social survey 2018: Frontier technologies for sustainable development. United Nations, 2018.

SANTOS, B. D. S. **A Crítica da razão indolente: contra o desperdício da experiência. Para um novo senso comum: a ciência, o direito ea política na transição paradigmática.** [S.l.]: Edições Afrontamento, 2000.

SARKER, M. Revolutionizing healthcare: the role of machine learning in the health sector. **Journal of Artificial Intelligence General science (JAIGS) ISSN: 3006-4023**, v. 2, n. 1, p. 36–61, 2024.

SARKER, S.; SARKER, S.; SIDOROVA, A. Understanding business process change failure: An actor-network perspective. **Journal of management information systems**, Taylor & Francis, v. 23, n. 1, p. 51–86, 2006.

SCHAFFERNAK, H.; MOESL, B.; URL, P.; KOGLBAUER, I. V.; VORRABER, W. Towards sustainable software quality in use: A review of measures. **Next Research**, Elsevier, p. 100680, 2025.

SCOTT, S. V.; ORLIKOWSKI, W. J. Entanglements in practice. **MIS quarterly**, JSTOR, v. 38, n. 3, p. 873–894, 2014.

SCOTT, S. V.; ORLIKOWSKI, W. J. Exploring ai-in-the-making: Sociomaterial genealogies of ai performativity. **Information and Organization**, Elsevier, v. 35, n. 1, p. 100558, 2025.

SELBST, A. D.; BOYD, D.; FRIEDLER, S. A.; VENKATASUBRAMANIAN, S.; VERTESI, J. Fairness and abstraction in sociotechnical systems. In: **Proceedings of the conference on fairness, accountability, and transparency.** [S.l.: s.n.], 2019. p. 59–68.

SIQUEIRA, S. W. M. Colaborar para destruir? sim, você é culpado (a)! sobre a ontologia produtivista dos sistemas colaborativos e nossa culpa no antropoceno. In: **SBC. Simpósio Brasileiro de Sistemas Colaborativos (SBSC)**. [S.l.], 2025. p. 176–186.

SLINGERLAND, G.; MURRAY, M.; LUKOSCH, S.; MCCARTHY, J.; BRAZIER, F. Participatory design going digital: challenges and opportunities for distributed place-making. **Computer Supported Cooperative Work (CSCW)**, Springer, v. 31, n. 4, p. 669–700, 2022.

SMALDINO, P. E. *et al.* Information architectures: a framework for understanding socio-technical systems. **npj Complexity**, Nature Publishing Group UK London, v. 2, n. 1, p. 13, 2025.

Sociedade Brasileira de Computação. **Grandes Desafios da Educação em Computação no Brasil 2025–2035**. Porto Alegre: Sociedade Brasileira de Computação, 2025. Licença Creative Commons Atribuição 4.0 (CC-BY). ISBN 978-85-7669-642-1.

Sociedade Brasileira de Computação. **II GrandSI-BR: Grandes Desafios de Sistemas de Informação no Brasil 2026–2036**. Porto Alegre: SBC, 2025. 131 p.

SOMANATH, S. *et al.* Exploring the composite intentionality of 3d printers and makers in digital fabrication. **International Journal of Design**, National Taiwan University of Science and Technology, v. 16, n. 3, p. 77–95, 2022.

SØNDERGAARD, M. L. J. *et al.* Fabulation as an approach for design futuring. In: **Proceedings of the 2023 ACM Designing Interactive Systems Conference**. [S.l.: s.n.], 2023. p. 1693–1709.

SOUSA, J. R. de; SANTOS, S. C. M. dos. Análise de conteúdo em pesquisa qualitativa: modo de pensar e de fazer. **Pesquisa e debate em Educação**, v. 10, n. 2, p. 1396–1416, 2020.

STÅHL, A.; BALAAM, M.; COMBER, R.; SANCHES, P.; HÖÖK, K. Making new worlds–transformative becomings with soma design. In: **Proceedings of the 2022 Chi conference on human factors in computing systems**. [S.l.: s.n.], 2022. p. 1–17.

STEAD, M.; COULTON, P. Sustainable technological futures: Moving beyond a one-world-world perspective. In: **Nordic Human-Computer Interaction Conference**. [S.l.: s.n.], 2022. p. 1–17.

STEAD, M. *et al.* More-than-human-data interaction: bridging novel design research approaches to materialise and foreground data sustainability. In: **Proceedings of the 25th International Academic Mindtrek Conference**. [S.l.: s.n.], 2022. p. 62–74.

STENGERS, I. A constructivist reading of process and reality. **Theory, Culture & Society**, Sage Publications Sage UK: London, England, v. 25, n. 4, p. 91–110, 2008.

STENGERS, I. **Cosmopolitics**. [S.l.]: University of Minnesota Press Minneapolis, 2010. v. 1.

STEPHANIDIS, C. *et al.* Seven hci grand challenges revisited: Five-year progress. **International Journal of Human–Computer Interaction**, Taylor & Francis, p. 1–49, 2025.

SUSEN, S. Reflections on the (post-) human condition: Towards new forms of engagement with the world? **Social Epistemology**, Taylor & Francis, v. 36, n. 1, p. 63–94, 2022.

TÄHTINEN, J.; HAVILA, V. Conceptually confused, but on a field level? a method for conceptual analysis and its application. **Marketing Theory**, SAGE Publications Sage UK: London, England, v. 19, n. 4, p. 533–557, 2019.

TALIAFERRO, R. C. The concept of matter in descartes and leibniz. In: **The Concept of Matter in Descartes and Leibniz**. [S.l.]: University of Notre Dame, 1964. v. 9, p. 1–34.

THOLANDER, J.; JONSSON, M. Design ideation with ai-sketching, thinking and talking with generative machine learning models. In: **Proceedings of the 2023 ACM designing interactive systems conference**. [S.l.: s.n.], 2023. p. 1930–1940.

TORRE, P. G. de la; PÉREZ-VERDUGO, M.; BARANDIARAN, X. E. Attention is all they need: Cognitive science and the (techno) political economy of attention in humans and machines. **AI & SOCIETY**, Springer, p. 1–17, 2025.

TUSSYADIAH, I. P.; JUNG, T. H.; DIECK, M. C. T. Embodiment of wearable augmented reality technology in tourism experiences. **Journal of Travel research**, SAGE Publications Sage CA: Los Angeles, CA, v. 57, n. 5, p. 597–611, 2018.

United Nations. **Pact for the Future, Global Digital Compact and Declaration on Future Generations**. New York: [s.n.], 2024. <https://www.un.org>. Summit of the Future Outcome Documents.

VELMANS, M. Dualism, Reductionism, and Reflexive Monism. In: VELMANS, M.; SCHNEIDER, S. (Ed.). **The Blackwell Companion to Consciousness**. Malden, MA, USA: Blackwell Publishing, 2007. p. 346–358. ISBN 9780470751466 9781405120197. Disponível em: <https://onlinelibrary.wiley.com/doi/10.1002/9780470751466.ch28>.

VENTURINI, T.; MUNK, A. K. **Controversy mapping: A field guide**. [S.l.]: John Wiley & Sons, 2021.

VERBEEK, P. P. Artifacts and attachment. a post-script philosophy of mediation. In: **Inside the politics of technology**. [S.l.]: Amsterdam University Press, 2005.

VERBEEK, P.-P. **What things do: Philosophical reflections on technology, agency, and design**. [S.l.]: Penn State Press, 2005.

VERBEEK, P.-P. **Moralizing technology: Understanding and designing the morality of things**. [S.l.]: University of Chicago press, 2011.

VERBEEK, P.-P. Expanding mediation theory. **Foundations of science**, Springer, v. 17, n. 4, p. 391–395, 2012.

VERBEEK, P.-P. Cover story beyond interaction: a short introduction to mediation theory. **interactions**, ACM New York, NY, USA, v. 22, n. 3, p. 26–31, 2015.

VERBEEK, P.-P. Toward a theory of technological mediation: A program for postphenomenological research. In: **Technoscience and postphenomenology: The Manhattan papers**. [S.l.]: Lexington Books, 2016. p. 189.

VOROS, J. A generic foresight process framework. **foresight**, MCB UP Ltd, v. 5, n. 3, p. 10–21, 2003.

VOROS, J. Big history and anticipation: Using big history as a framework for global foresight. **Handbook of anticipation: Theoretical and applied aspects of the use of future in decision making**, Springer International Cham, p. 1–40, 2017.

WAHLIN, D. W.; BLOMKAMP, D. E. Making global local: Global methods, local planning, and the importance of genuine community engagement in australia. **Policy Design and Practice**, Taylor & Francis, v. 5, n. 4, p. 483–503, 2022.

WAKKARY, R.; OOGJES, D.; BEHZAD, A. Two years or more of co-speculation: polylogues of philosophers, designers, and a tilting bowl. **ACM Transactions on Computer-Human Interaction**, ACM New York, NY, v. 29, n. 5, p. 1–44, 2022.

WAKKARY, R.; OOGJES, D.; SAKIB, N.; BEHZAD, A. Turner boxes and bees: From ambivalence to diffraction. In: **Proceedings of the 2023 ACM Designing Interactive Systems Conference**. [S.l.: s.n.], 2023. p. 790–807.

WALSHAM, G. Actor-network theory and its research: current status and future prospects. **Information systems and qualitative research**, Springer, p. 466–480, 1997.

WALSHAM, G.; SAHAY, S. Gis for district-level administration in india: problems and opportunities. **MIS quarterly**, JSTOR, p. 39–65, 1999.

WANG, Y. *et al.* Who uses personas in requirements engineering: The practitioners' perspective. **Information and Software Technology**, Elsevier, v. 178, p. 107609, 2025.

WESSELLS, A. T. **Reassembling the Social: An Introduction to Actor-Network-Theory by Bruno Latour: A Review of: "Reassembling the Social: An Introduction to Actor-Network-Theory. Bruno Latour. New York: Oxford University Press, 2005. 312 pages. ISBN: 0199256047"**. [S.l.]: Taylor & Francis, 2007.

WHITEHEAD, A. N. **An enquiry concerning the principles of natural knowledge**. [S.l.]: University press, 1925.

WHITEHEAD, A. N.; DOUCHEMENT, J. **The concept of nature**. [S.l.]: Springer, 1920. v. 190.

WIJARNARKO, A. F.; MAHARANI, S. D. Human's relationship with technology in nickel land's accelerationism. **Jurnal Filsafat**, v. 34, n. 1, p. 1–22, 2024.

WINNER, L. **Autonomous technology: Technics-out-of-control as a theme in political thought**. [S.l.]: Mit Press, 1978.

WINNER, L. Do artifacts have politics? In: **Computer ethics**. [S.l.]: Routledge, 2017. p. 177–192.

WOLFF, B.; KELTER, L.; SCHLAGWEIN, D.; SCHODER, D. Is information systems research concerned with societal grand challenges? In: **ECIS**. [S.l.: s.n.], 2022.

XI, L. Modern education: Advanced prediction techniques for student achievement data. **International Journal of Advanced Computer Science & Applications**, v. 15, n. 1, 2024.

YE, Y.; ZHANG, D. Co-creating pluralistic futures: A systematic literature review on participatory speculative design. **DRS Biennial Conference Series**, 2024.

YELAVICH, S.; ADAMS, B. **Design as future-making**. [S.l.]: Bloomsbury Publishing, 2014.

ZHU, L.; CHAO, C.; FU, Z. How hci integrates speculative thinking to envision futures. **Journal of Futures Studies**, v. 28, n. 4, 2024.

ZORZO, A. F. *et al.* **Referenciais de Formação para os Cursos de Graduação em Computação**. [S.l.]: SBC, 2017.

ZUBOFF, S. Surveillance capitalism and the challenge of collective action. In: SAGE PUBLICATIONS SAGE CA: LOS ANGELES, CA. **New labor forum**. [S.l.], 2019. v. 28, n. 1, p. 10–29.

ZUBOFF, S. The age of surveillance capitalism. In: **Social theory re-wired**. [S.l.]: Routledge, 2023. p. 203–213.

ZUPIC, I.; ČATER, T. Bibliometric methods in management and organization. **Organizational research methods**, Sage Publications Sage CA: Los Angeles, CA, v. 18, n. 3, p. 429–472, 2015.

Appendix A

Detailed Bibliometric Analysis

A.1 Method

We conducted a bibliometric study on the evolution of the scientific literature concerning Entanglement Theories in Information Systems (IS) and related fields. The methodological approach adopted follows a bibliometric analysis framework inspired by (Öztürk *et al.*, 2024), which outlines four sequential stages for conducting bibliometric research.

The first stage defines the research objective, identifying the research questions, expected outcomes, and the overall scope of the investigation. The second stage concerns data collection on the relevant literature and involves selecting the databases, identifying search terms, and applying inclusion and exclusion criteria. The third stage pertains to analysis and visualization, requiring the identification of bibliometric techniques aligned with the research objective and scope; the selection of appropriate software for analysis and visualization; and the subsequent examination of the data and visualization of the findings. Finally, the fourth stage concerns the interpretation of results, assessing whether the research questions were effectively addressed, whether the study offers new insights into the relevant literature, and proposing avenues for future research.

Our guiding research question is (RQ): “How have Entanglement Theories been explored in IS literature and related fields over time?” Additional and more specific information regarding our investigation can be found in the referenced Table 28.

A.1.1 Language and Search String

For this bibliometric analysis, the search was conducted in English. The goal was to ensure broad coverage of the central concepts defined in the research protocol, encompassing both Entanglement Theories and the field of IS. Regarding the theories, the search included their primary denominations, terminological variations, and the most relevant subareas, such as Object-Oriented Ontology (OOO), a development within Speculative Realism, and Theory of Technological Mediation, associated with Postphenomenology.

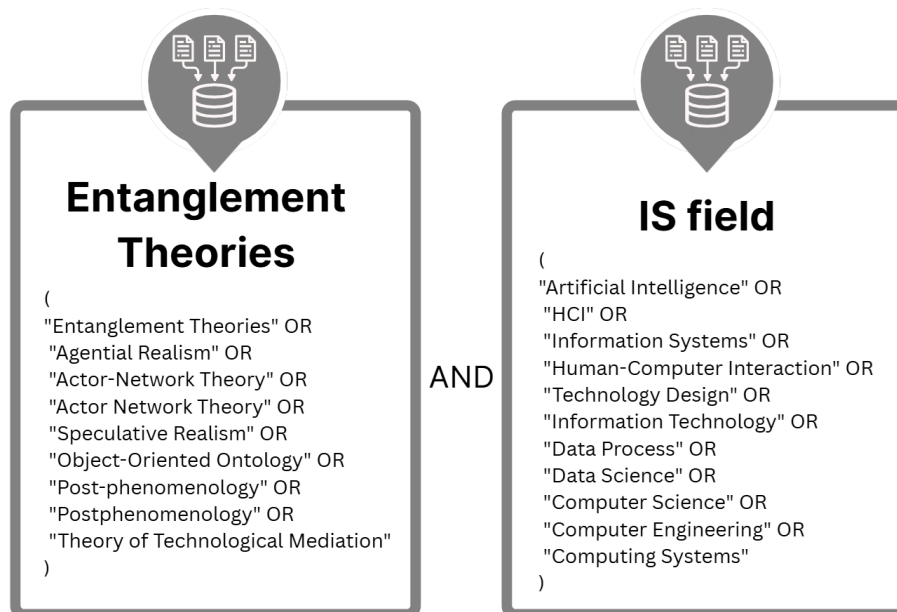
To represent the IS field, we selected terms widely recognized and associated with

Table 28: Detailed Research Sub-Questions

Code	Research Sub-Question	Type of Analysis	Indicators
RQ1	How has the scientific production on Entanglement Theories in IS and related fields evolved over time, considering publication volume, document types, and patterns of author collaboration?	Performance	General Overview and Annual Article Publication
RQ2	Which works are most highly cited, and how have their citation patterns evolved over time?	Performance	Evolution of Average Citations per Year, Most Cited Articles
RQ3	Who are the leading authors, and how are their collaboration networks structured?	Performance	Main Authors and Timeline of Their Scholarly Output, Author Collaboration Network
RQ4	How do the main theoretical references relate to the leading authors and the topics addressed, as indicated by the keywords of their publications?	Performance / Science Mapping	Most Cited References, Three-Field Plot: Most Cited References × Leading Authors × Keywords
RQ5	What are the major themes and theoretical approaches that emerge from keyword analysis over time?	Science Mapping	Word Cloud, Keyword Co-occurrence Network, Emerging Themes

the discipline, such as IS and Information Technology, which cover studies on IT governance, digital infrastructure, and organizational transformation. Terms such as “Technology Design”, “HCI”, and “Human-Computer Interaction” indicate an interest in approaches focused on technological design, sociotechnical mediation, and the social and ethical impacts of technology, topics central to contemporary IS research. Expressions like “Data Process” and “Data Science” reflect the rise of data-driven approaches used to generate organizational intelligence, automate decision-making, and identify patterns within digital ecosystems. Finally, “Artificial Intelligence” was included as a rapidly expanding domain that has strongly influenced current debates in both IS and the broader Computing field.

The search string was executed on February 10, 2025, in the Scopus and Web of Science databases. Figure 42 presents the search expression used in this study.

Figure 42: Base Search String

Source: Author's elaboration.

A.1.2 Inclusion and Exclusion Criteria

The bibliometric analysis conducted in this study encompassed a careful selection of documents retrieved using the previously reported search string. To be included in the dataset, documents were required to meet one or more of the predefined Inclusion Criteria (IC). Table 29 provides a detailed description of these specific criteria, establishing the basis for document inclusion in the bibliometric analysis.

Table 29: Inclusion Criteria for Document Selection

Item	Criterion Description
IC1	Include original research articles, review papers, and conference publications related to Entanglement Theories in IS.
IC2	Documents must directly address Entanglement Theories within the field of IS.

Source: Author's elaboration.

Documents that met one or more of the predefined Exclusion Criteria (EC) were removed from our dataset. The specific criteria applied for excluding documents are detailed in Table 30.

Table 30: Exclusion Criteria for Document Selection

Item	Criterion Description
EC1	Exclude documents not written in English.
EC2	Exclude documents that mention entanglement but do not focus on the theories or their applications in IS.
EC3	Exclude documents from sources that do not meet academic standards, such as non-peer-reviewed venues.
EC4	Exclude duplicate entries or multiple versions of the same work.

Source: Author's elaboration.

A.1.3 Selection of Scientific Databases

In selecting the digital libraries for this study, we adopted the criteria presented in Table 31:

Considering these criteria, we selected two databases: the Web of Science (WoS) and Scopus. It is important to note that both databases offer built-in bibliometric tools that provide detailed analyses within their respective platforms. However, we chose not to use these internal tools, as our aim was to combine and jointly analyze the results obtained from both databases while removing duplicate records. The bibliometric tools integrated into WoS and Scopus operate independently and do not support direct data integration across platforms.

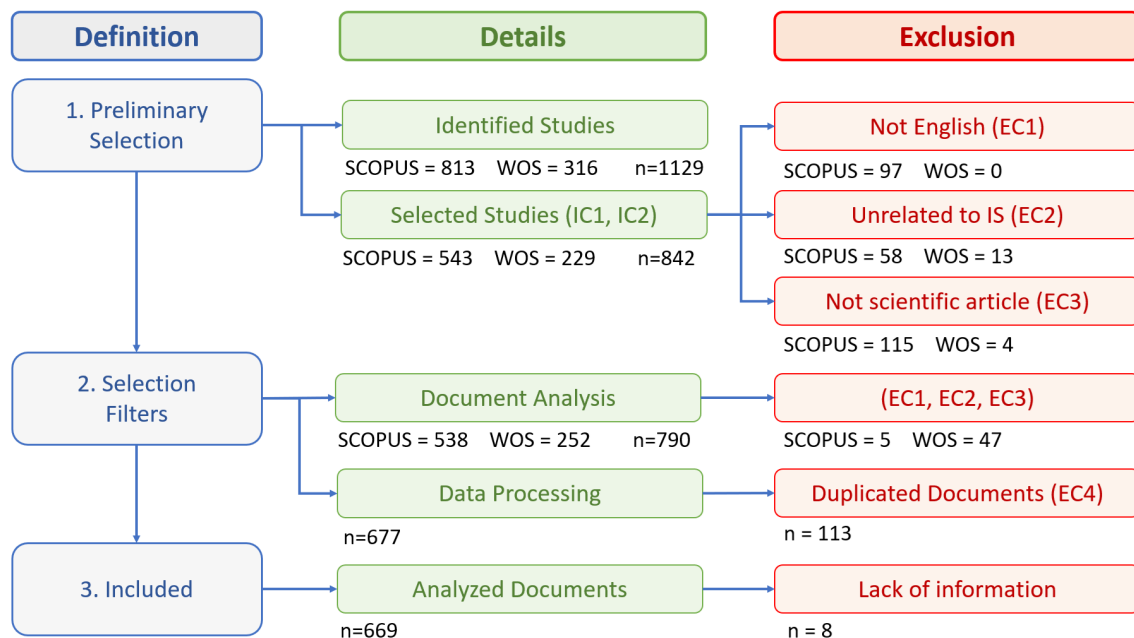
Table 31: Criteria for Selecting Databases for Bibliometric Analysis

Item	Criterion Description
C1	Search tools with support for logical expressions and advanced search operators.
C2	Search mechanisms that ensure unique and non-duplicated results for identical keywords.
C3	Ability to export results and citations in formats compatible with bibliometric software.
C4	Possibility of integrating results from different databases for a unified bibliometric analysis.

Source: Author's elaboration.

A.1.4 Selection Procedures

The selection of documents was conducted through a structured three-stage process, as illustrated in Figure 43. This method is based on an adaptation of the model proposed by (Page *et al.*, 2021), which guides the conduction of literature reviews through clear directives and a structured workflow involving stages such as identification, screening, eligibility, and inclusion of studies. The model aims to ensure transparency and reproducibility in the review process by documenting the number of studies identified, excluded, and selected at each stage of the analysis.

Figure 43: Identification and selection process

Source: Author's elaboration, adapted from Page *et al.* (2021).

Stage 1 – Preliminary Selection: Initial searches were conducted in the Scopus and Web of Science (WoS) databases using search strings designed to capture the diversity of scientific publications related to Entanglement Theories in IS and related areas. This stage resulted in the identification of 813 documents in Scopus and 316 in WoS, totaling

1,129 preliminary studies that served as the foundation for the subsequent screening and analysis phases.

Stage 2 – Selection Filters: To refine the initial sample, we applied thematic filters in both databases with the goal of restricting the results to the scope of IS and related fields. In the Web of Science (WoS), the following subject areas were considered: Computer Science, Information Science, Business, Education Research, Operations Research, and Technology, resulting in the selection of 299 documents. In Scopus, similar criteria were applied, resulting in 543 records. These 842 selected documents were saved in the files `scopus.bib` and `wos.bib`, forming the basis for the next stage of more detailed document analysis.

For metadata analysis, we used the Parsif.al¹ platform, which facilitated the organization and initial processing of the selected documents. In this stage, we evaluated titles, abstracts, languages, and publication venues according to predefined inclusion and exclusion criteria. Irrelevant, duplicate, or inconsistent records were removed. In total, 790 documents were deemed relevant and retained for the subsequent steps. The updated references were saved in the `scopus.bib` and `wos.bib` files.

For data processing, we developed an R script to consolidate the data retrieved from the selected databases using the `scopus.bib` and `wos.bib` files. During this process, 113 duplicate records were removed. The resulting integrated dataset contained 677 valid documents.

Stage 3 - Included: In this final stage, 8 incomplete records were removed from the consolidated dataset. The final corpus, consisting of 669 documents, was exported to the Biblioshiny tool, where the descriptive and exploratory bibliometric analyses were conducted.

Document screening was based on reading titles, abstracts, and keywords, carried out by a single reviewer. Although the process followed rigorous criteria, we acknowledge the absence of independent double coding as a limitation. Future studies should incorporate inter-rater procedures to enhance data reliability and mitigate selection bias.

A.1.5 Data Analysis

The data analysis in this bibliometric study was conducted with the aim of answering the central research question and the four subquestions detailed in Table 28. To this end, we employed quantitative and exploratory techniques based on a consolidated dataset of 669 documents extracted from the Scopus and Web of Science databases and processed using the Biblioshiny tool.

A.1.5.1 Annual Article Production

The first stage of the analysis, addressing subquestion RQ1, examined the general landscape of the literature on Entanglement Theories in IS. Descriptive metrics were extracted, including annual article production, growth rate, document types, and authorship distribution. Our goal was to understand the evolution and increasing

¹ Available at: <https://parsif.al/>

scholarly interest in Entanglement Theories within IS, identifying trends, research peaks, international contributions, and the temporal dynamics of engagement with the topic. These metrics provide a macro-level temporal overview of the theme within the IS field.

A.1.5.2 Citation Analysis

Regarding subquestion RQ2, which investigates the academic impact of publications, we analyzed the average number of citations of the 669 works over time, along with the identification of the most cited studies. The analysis included calculating citations per document and identifying those articles with the highest bibliometric relevance within the sample, indicating their influence and prominence in the scientific community (Bornmann *et al.*, 2008). This allows for an understanding of the influence and usefulness of the studies, serving as a reliable metric of academic recognition (Zupic; Čater, 2015; Bornmann; Daniel, 2007).

A.1.5.3 Authorship Analysis

To address subquestion RQ3, related to authorship and collaboration networks, we mapped the leading authors in the dataset, including the evolution of their scholarly output and the structure of their co-authorship networks. This analysis normalized citation counts by the time elapsed since publication, enabling a fair comparison between older works, which have had more time to accumulate citations, and more recent ones. Additionally, we included the metric of Time-Normalized Citations, Total Citations per Year (TCpY), calculated as the total number of citations divided by the number of years since publication, providing a fairer assessment of long-term impact.

A.1.5.4 Reference Analysis

To address subquestion RQ4, which examines the articulation between major theoretical references, leading authors, and the topics they explore, we identified the most frequently cited references across the 669 documents in the dataset. We then constructed a three-field plot visualizing the connections among these references, the most productive authors, and the primary keywords used in their publications.

A.1.5.5 Thematic Analysis

Finally, subquestion RQ5, focused on thematic evolution and theoretical approaches, was initially examined through a word cloud generated from the keywords of the documents. We then conducted a co-occurrence analysis to understand how these terms relate to each other, followed by a mapping of the temporal evolution of concepts to identify potential transitions and theoretical consolidations within the field. Based on the analyzed data, we present a set of results organized according to the research subquestions.

A.2 Results and Discussion

We present the results based on the research questions, seeking to understand how Entanglement Theories have been mobilized in IS and what trends, challenges, and opportunities emerge from this landscape.

A.2.1 Overview of Research on Entanglement Theories in IS

To understand the development and consolidation of Entanglement Theories within IS (RQ1), we analyzed the evolution of the scientific production on the topic over time. Specifically, we examined publication volume, document types, and patterns of author collaboration.

The data presented in Table 32 reveal that research on Entanglement Theories in IS displays a pattern of steady growth, although accompanied by signs of theoretical maturation and challenges in collaborative consolidation.

Table 32 presents an initial set of bibliometric indicators derived from the analysis.

Table 32: General Overview of the Bibliometric Data

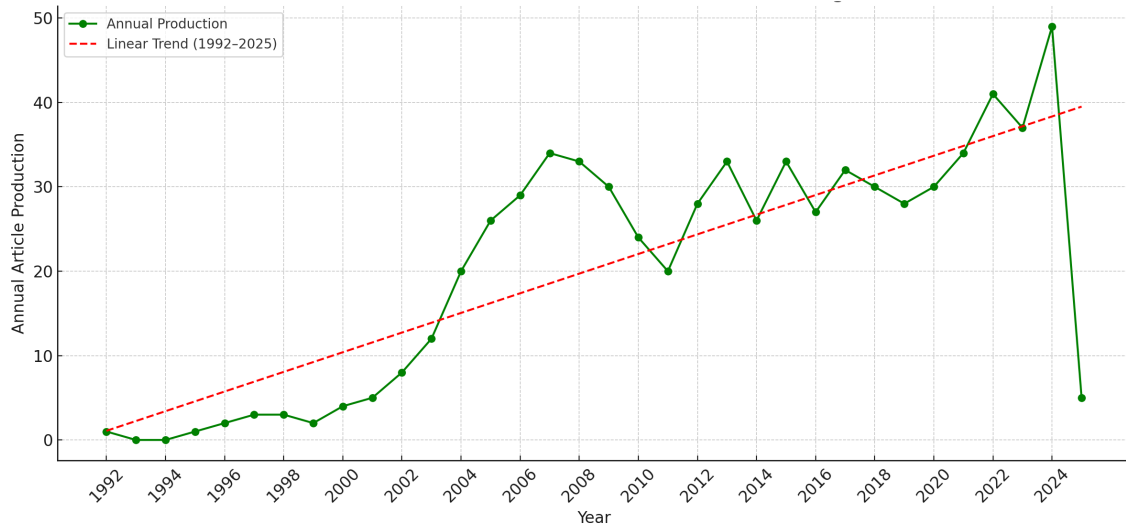
Description	Quantity
Main Information about the Data	
Period	January 1, 1992 to January 29, 2025
Sources	450 journals, books, etc.
Documents	A total of 669 analyzed documents
Annual Growth	Annual growth rate of 5%
Average Age	Average document age: 10.8 years
Citations per Document	Average of 17.23 citations per document
References	Total of 4,943 cited references
Authors	
Number of Authors	A total of 1,142 authors
Single-Authored Docs.	210 documents written by a single author
Co-authors per Doc.	Average of 2.26 co-authors per document
International Collaboration %	4.634% of documents involved international collaboration
Document Types	
Articles	304 articles published in scientific journals
Conference Papers	235 studies presented at conferences or symposia
Reviews	2 review papers
Others	128 documents including editorials, notes, and special issue introductions

Source: Author's elaboration.

The bibliometric analysis based on 669 documents published between 1992 and January 2025 reveals an average annual growth rate of 5%, indicating a continuous expansion of academic interest in the topic. However, the graph in Figure 44, which presents the yearly variations in the number of published articles, shows that this growth is not linear.

A marked increase can be observed between 2003 and 2008, followed by oscillations that reflect alternating peaks and declines in annual scholarly output, with a more consistent rise beginning in 2020. The apparent sharp decline in 2025 should be interpreted with caution, as the data for that year correspond only to the month of January, reflecting a partial dataset.

Figure 44: Annual Production of Studies



Source: Author's elaboration using the Biblioshiny tool.

This pattern suggests that, although the field is expanding, it has not yet consolidated into a community with a stable editorial dynamic. The average age of the documents is 10.8 years, which paradoxically indicates a substantial body of studies without necessarily reflecting consolidated theoretical or methodological maturity. A plausible explanation lies in the diversity and dispersion of the approaches grouped under the label “Entanglement Theories,” which have only recently begun to gain more unified visibility.

With regard to academic collaboration, the data show that only 210 documents (approximately 31%) are single-authored, while the overall average is 2.26 co-authors per document.

International collaboration remains limited, as only 4.63% of the documents result from partnerships between authors from different countries. Table 33 corroborates this finding by indicating that, even among the countries with the highest publication volume, national authorship (Single Country Publication - SCP) predominates. The United States leads in international collaborations (Multiple Country Publication - MCP = 4).

Table 33: Country-Level Production and International Collaboration

Country	Articles	SCP	MCP
United Kingdom	82	80	2
USA	77	73	4
Australia	55	52	3
Sweden	25	23	2
Canada	19	16	3
China	17	16	1
Germany	14	11	3
Finland	12	11	1
Italy	11	9	2
Austria	9	7	2

Source: Author's elaboration.

The academic impact of the field shows an overall average of 17.23 citations per document, a reasonable indicator that may nonetheless be inflated by a small number of highly cited works. A total of 4,943 distinct references were cited, which may suggest an extensive theoretical foundation.

An important finding concerns the distribution of document types. Of the total analyzed, 304 documents (approximately 45%) are journal articles, followed by 235 conference papers (35%). Only two documents were classified as systematic reviews, which indicates a critical gap in the organization and evaluation of the state of the art. This shortage of review studies is concerning for a field still in consolidation, since the absence of structured syntheses may hinder the development of theoretical, conceptual, and methodological consensus. In addition, the significant number of documents categorized as “Other” (128 records), including editorial notes, introductions, and peripheral texts, may indicate that the field is still seeking legitimation and clearer definition within formal scientific channels.

Taken together, these results reveal a field that is promising, expanding, and increasingly interdisciplinary, but that still faces important challenges: consolidating a more integrated theoretical identity, expanding international collaboration networks, and stabilizing its scientific production in a more continuous manner.

Despite the integrative potential of Entanglement Theories, their combination requires attention to the ontological tensions between approaches that adopt distinct views on entities, relations, and the constitution of reality. Such integration demands methodological caution and clarity regarding the ontological and epistemological premises of each theory, in order to avoid collapsing fundamental differences into a generic notion of “entanglement.”

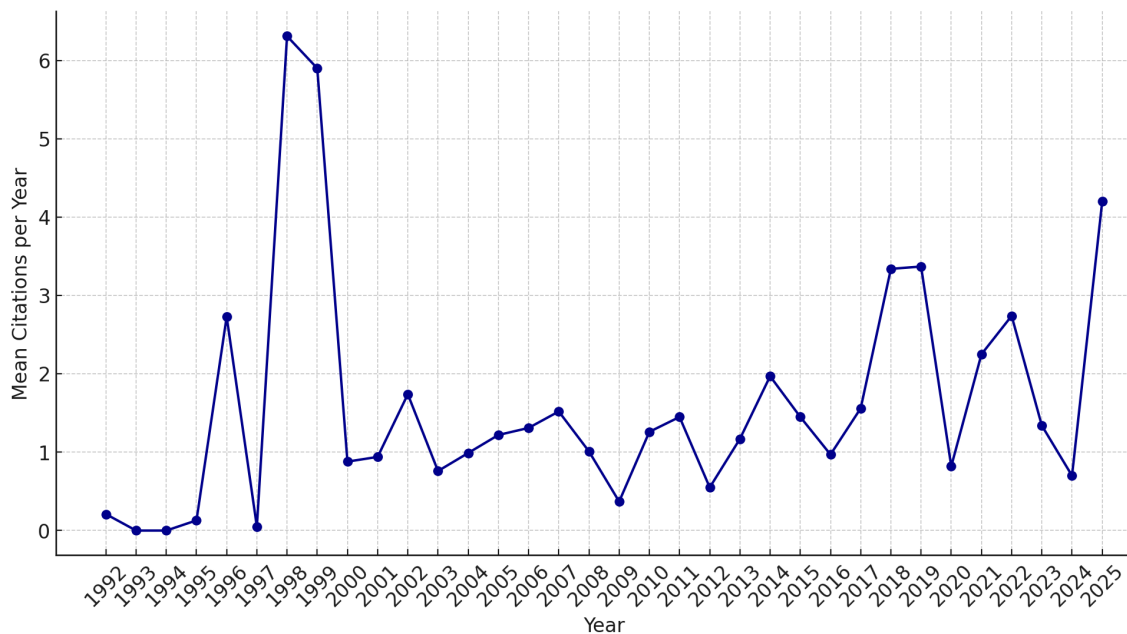
A.2.2 Evolution of Academic Impact

To identify the main theoretical references associated with Entanglement Theories in IS, we analyzed the most cited works in the scientific literature and examined how their citation patterns have evolved over time (RQ2). By analyzing the number of citations and their temporal evolution, we sought to understand the impact and longevity of these works within the field. This approach makes it possible to recognize significant contributions, observe potential changes in the centrality of certain authors or studies over the years, and trace the trajectory of the conceptual consolidation of the area.

Figure 45 presents the graph of the annual average of the Total Citations per Year (TCpY) metric for the documents, considering the period from their publication until January 29, 2025. The TCpY metric is calculated individually for each document by dividing the total number of citations received by the number of years since publication. By calculating the average TCpY per year of publication, the analysis enables a fairer comparison of the average impact of documents over time by normalizing exposure effects.

The graph reveals marked oscillations, characterized by concentrated peaks and abrupt drops that require careful interpretation. The first noteworthy point appears between the late 1990s and early 2000s, particularly in 1999 and 2000, when the average number of

Figure 45: Average Citations per Year Over Time



Source: Author's elaboration using the Biblioshiny tool.

citations reaches its highest values. This behavior may be related to the publication of pioneering or highly influential works. It is worth noting that, during this period, only ANT and Postphenomenology were already consolidated, with more than a decade since their seminal milestones. Even so, it is not possible to determine whether this peak reflects the concentrated impact of a small number of highly influential publications or a broader and more homogeneous diffusion of scientific output.

From 2001 onward, the average number of citations shows relative stability, with modest variations, which suggests a phase of theoretical dispersion and an absence of central themes. This trend may indicate that Entanglement Theories were still circulating peripherally in IS research, being mobilized in sporadic and non-articulated ways.

A positive inflection point is observed from 2017 onward, when the average number of citations begins a trajectory of sustained growth, reaching a new level between 2018 and 2019. However, this trend is abruptly interrupted in 2020, when the average number of citations undergoes a steep decline.

This drop coincides with the onset of the COVID-19 pandemic and can be interpreted as a reflection of the disruptive effects caused by the global health crisis. Studies have shown that the pandemic negatively affected scientific production in several fields (Gao *et al.*, 2021). In addition, many journals prioritized pandemic-related studies, shifting editorial focus and delaying the evaluation of works outside this scope. Although caution is needed to avoid assuming a direct causal relationship, the alignment with studies on the impact of COVID-19 on science supports this interpretation (Holly, 2020; Gupta *et al.*, 2021).

From 2021 onward, the average number of citations shows signs of recovery, with a new peak in 2025. However, this most recent value must be interpreted with caution, as

it refers to a year still in progress and therefore subject to distortions. Overall, the graph reveals a field that is still consolidating, with occasional peaks of impact and a trajectory of increasing recognition that was temporarily interrupted.

In addition, Table 34 presents the works within the sample of 669 documents that received the highest number of citations from sources external to the initial dataset, highlighting those with the greatest relevance and impact in the broader scientific landscape.

Table 34: Most Cited Works from External Sources (Ordered by TCpY)

Title	Author	TC	TCpY
Entanglement HCI: The next wave?	(Frauenberger, 2019)	299	42.71
Embodiment of wearable augmented reality technology in tourism experiences	(Tussyadiah <i>et al.</i> , 2018)	239	29.88
Entanglements in practice	(Scott; Orlikowski, 2014)	242	20.17
The end of geography or the explosion of place? Conceptualizing space, place and information technology	(Graham, 1998)	481	17.18
GIS for district-level administration in India: Problems and opportunities	(Walsham; Sahay, 1999)	447	16.56
Actor-Network Theory and its role in understanding the implementation of information technology developments in healthcare	(Cresswell <i>et al.</i> , 2010)	226	14.13
Narrative networks: Patterns of technology and organization	(Pentland; Feldman, 2007)	284	14.95
Implementing innovation in construction: Contexts, relative boundedness and actor-network theory	(Harty, 2008)	202	11.22
Understanding business process change failure: An actor-network perspective	(Sarker <i>et al.</i> , 2006)	221	11.05
Accumulating and coordinating: Occasions for information technologies in medical work	(Berg, 1999)	189	7.00

Source: Author's elaboration.

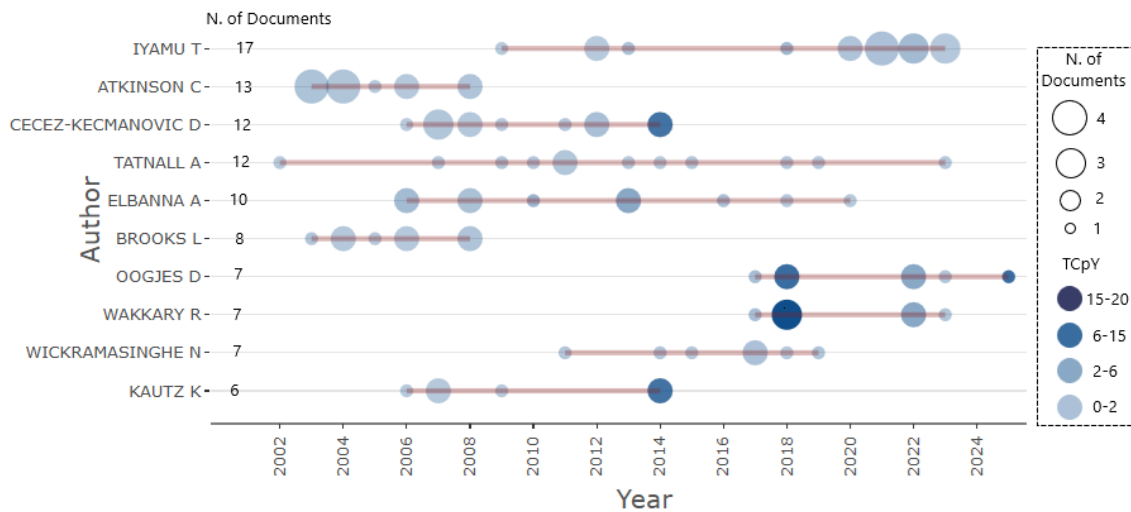
A.2.3 Production Dynamics and Collaboration Among Leading Authors

This section presents the most productive authors within the analyzed sample, examining both the temporal evolution of their publications and the collaborative ties established over time (RQ3). Our goal is to understand the academic connections that structure the field and to identify cooperation patterns that support the collective construction of knowledge. Figure 46 shows the annual distribution of publications for each author, along with the TCpY metric.

Some authors, such as Tiko Iyamu (IYAMU T), Arthur Tatnall (TATNALL A), and Amany R. Elbanna (ELBANNA A), display trajectories characterized by continuity and stability over the years. Iyamu, for instance, shows a regular publication pattern between 2008 and 2023, although with relatively modest impact (TCpY between 0 and 2), suggesting consistent activity but limited citation visibility. Tatnall maintains a long-standing presence with sporadic publications since the early 2000s, while Elbanna concentrates her output between 2006 and 2020, also with moderate bibliometric impact. These patterns suggest consolidated yet not highly visible lines of research.

In contrast, more recent authors such as Ron Wakkary (WAKKARY R) and Doenja Oogjes (OOGJES D), with seven publications each, stand out due to the high impact of their contributions. The dark blue bubbles, particularly between 2018 and 2019, indicate TCpY values above 15, signaling recent yet already influential scholarly activity. The absence of publications in the earlier years reinforces the emerging nature of these researchers, whose work is strongly aligned with contemporary approaches such as

Figure 46: Publication Chronology of Leading Authors



Source: Author's elaboration using the Biblioshiny tool.

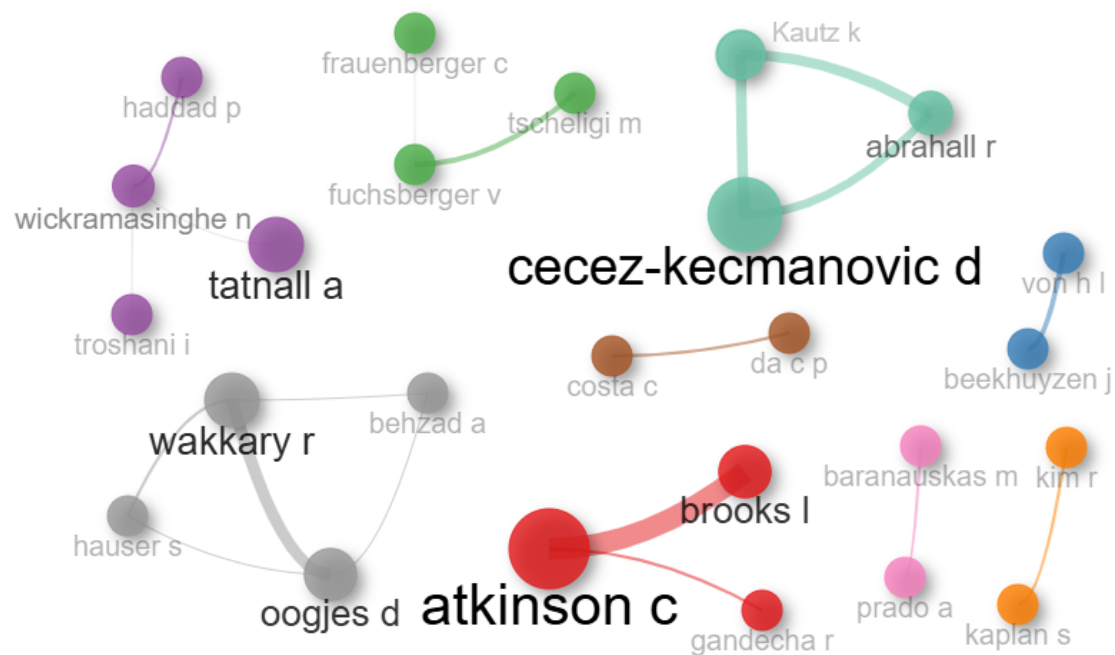
Speculative Design, Entanglement Theories, and posthumanist perspectives applied to HCI.

Beyond individual production, it is essential to investigate whether these authors work in isolation or as part of collaborative networks. Mapping these connections makes it possible to identify underlying dynamics of knowledge coproduction, reveal theoretical affinities, and expose ties that directly influence the development of the field. To this end, we compared the chronology of academic production with the structure of co-authorship networks. Figure 47 complements the temporal analysis from Figure 46 by visually presenting the network of collaborations among the leading researchers.

The network reveals well-defined collaborative clusters. One of the most consistent clusters is formed by Dubravka Cecez-Kecmanovic (cecez-kecmanovic d), with recurring collaborations with Karlheinz Kautz (kautz k) and Rebecca Abrahall (abrahall r), indicating a consolidated tradition of joint research, particularly between 2003 and 2014. Similarly, the partnership between Chris Atkinson (atkinson c) and Laurence Brooks (brooks l) shows high collaborative density and activity concentrated in the early years of the historical series, suggesting enduring institutional ties and theoretical alignment developed over time.

In contrast, a more recent and dynamic cluster emerges, composed of Ron Wakkary, Doenja Oogjes, Sabrina Hauser, and Armi Behzad. This group represents a new generation of researchers strongly aligned with critical, speculative, and distributed-agency approaches (Wakkary *et al.*, 2022; Somanath *et al.*, 2022; Wakkary *et al.*, 2023). The configuration of this network, marked by cross-collaborations and high bibliometric impact, points to a process of paradigmatic reconfiguration in the field, challenging traditional structures and indicating new methodological and epistemological directions.

Figure 47: Collaboration Network Among Authors



Source: Author's elaboration using the Biblioshiny tool.

A.2.4 Key References and Their Articulation with Authors and Themes

This subsection analyzes how the main external references related to studies on Entanglement Theories in IS (RQ4) connect with the most influential authors and the recurring themes identified through the publications' keywords. The aim is to understand how specific theoretical milestones guide scientific production in the field and how these foundational works are mobilized by different researchers and thematic areas. Table 35 presents an overview of the most cited references in the analyzed corpus, highlighting the texts that provide the theoretical grounding for investigations related to Entanglement Theories in IS.

Actor-Network Theory (ANT) stands out historically as the main theoretical and philosophical foundation in studies on Entanglement Theories in IS. Among the ten most cited titles, eight are authored or co-authored by Bruno Latour, Michel Callon, or John Law, the three principal founding figures of ANT.

Although expressive, this result is also expected, given that ANT is the most consolidated among the approaches analyzed. It reflects a clear preference for this theory within the observed scientific community and reveals a paradigmatic stabilization in which ANT serves as the primary gateway for thinking about sociotechnical relations and the distributed agency of humans and nonhumans.

However, understanding the centrality of an approach is not limited to recognizing its citation frequency. It also requires examining how it is mobilized in practice by researchers in the field. This demands moving beyond simple citation counts and investigating how these references interact with the production of the most influential

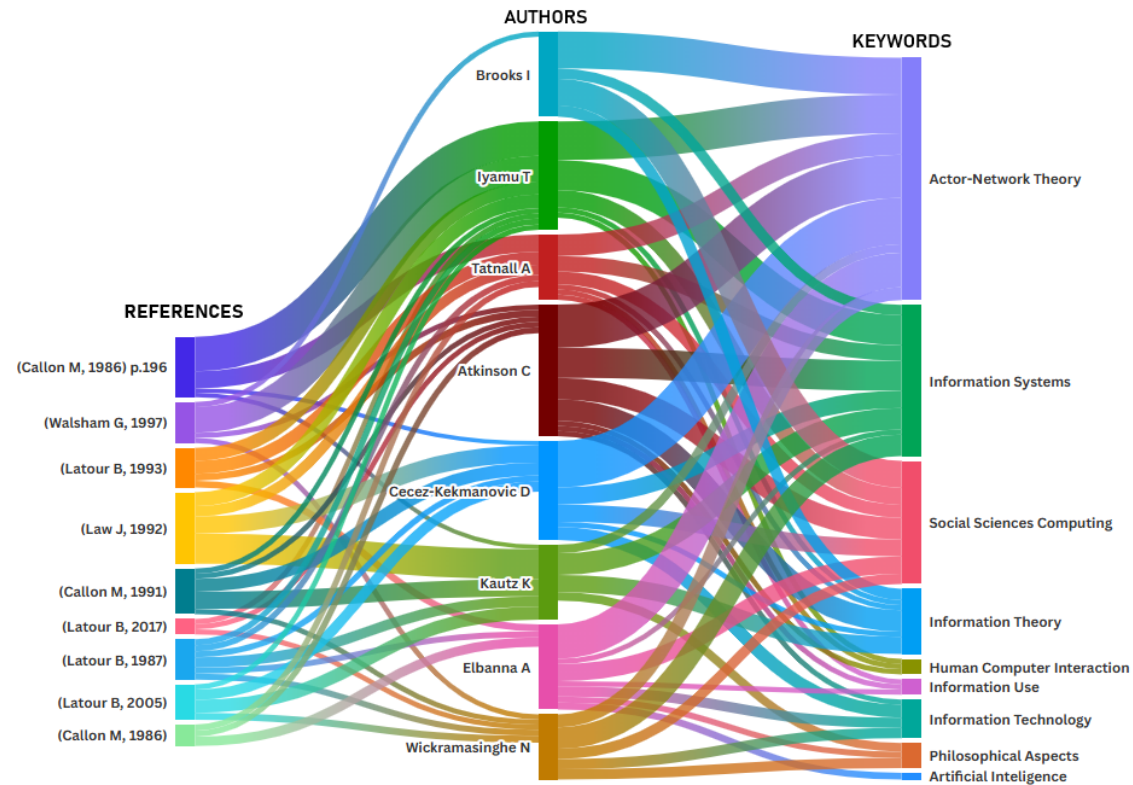
Table 35: Most Cited External References in the Analyzed Documents

Title	Author	Citations
Science in Action: How to Follow Scientists and Engineers Through Society	Bruno Latour	27
Sociological Review Monograph, P196	Michel Callon and John Law	21
Power, Action and Belief: A New Sociology of Knowledge?	Michel Callon and John Law	20
A Sociology of Monsters: Essays on Power, Technology, and Domination	John Law	20
Actor-Network Theory and IS Research: Current Status and Future Prospects	Geoff Walsham	17
Notes on the Theory of the Actor-Network: Ordering, Strategy, and Heterogeneity	John Law	16
Why Has Critique Run Out of Steam? From Matters of Fact to Matters of Concern	Bruno Latour	15
Making Things Public: Atmospheres of Democracy	Isabelle Stengers, Bruno Latour, and Peter Weibel	13
Reassembling the Social: An Introduction to Actor-Network-Theory	Bruno Latour	13
We Have Never Been Modern	Bruno Latour	12

Source: Author’s elaboration.

authors. In this context, Figure 9 establishes a connection between the leading authors identified earlier in Figure 46, the references most frequently cited by them, and the keywords associated with their publications. This visualization reveals how certain authors draw on specific theoretical milestones and articulate them with emerging themes, making visible patterns of theoretical alignment and intellectual trajectories.

Figure 48: Most Cited References by Leading Authors and the Most Prevalent Keywords



Source: Author’s elaboration using the Biblioshiny tool.

The diagram reveals a strong convergence among authors, references, and theoretical domains. Authors such as Atkinson C., Cecez-Kecmanovic D., Kautz K., and Elbanna A. maintain robust connections to the works of Latour, Callon, and Law, demonstrating a solid theoretical alignment with ANT. This adherence is also reflected in the keywords associated with their studies, such as “Actor-Network Theory,” “Information Systems,” and “Social Sciences Computing.”

While Cecez-Kecmanovic D. and Kautz K. associate the works of Latour and Callon predominantly with themes such as IS and Social Sciences Computing, authors like Wickramasinghe N. and Elbanna A. broaden the thematic scope by mobilizing these same references to engage with topics such as Information Technologies, Information Use, philosophical aspects, and even Artificial Intelligence. This diversification suggests that, although there is a shared theoretical foundation, there are significant variations in how these theories are appropriated and articulated in relation to contemporary issues.

A particularly relevant case is the presence of [Walsham \(1997\)](#), which appears among the most cited references with 17 mentions. Walsham was one of the pioneers in articulating ANT with qualitative IS research, emphasizing the analysis of interactions among technology, organizational context, and agency. His influence is visible among authors such as Iyamu T. and Brooks L., who appear to adopt this perspective to support investigations of a more interpretivist and sociotechnical nature.

Finally, The presence, still modest but conceptually promising, of the keyword “Artificial Intelligence” stands out within the analyzed set. Although it is not among the main terms associated with ANT in the more traditional authors, it appears linked to researchers who also draw on the works of Latour and Callon. This suggests an emerging attempt to connect discussions on distributed agency and materiality with the ethical and epistemic challenges posed by artificial intelligence. This developing connection indicates that Entanglement Theories are beginning to be mobilized to problematize AI beyond its characterization as a purely technical tool.

A.2.5 Thematic Evolution and Emerging Theoretical Approaches

To identify emerging trends, shifts in research focus, and the development of new conceptual perspectives over time (RQ5), we examined the evolution of themes and theoretical approaches based on a temporal analysis of the keywords used in the publications. These transformations allow us to understand how the field has been restructured in response to theoretical advancements, interdisciplinary influences, and new challenges, revealing both continuity and innovation within this area of research.

Figure [49](#) visually presents the frequency of keywords appearing in the 669 analyzed documents. To improve the visual balance of the word cloud and provide a more proportional perception of the terms, we applied a square-root transformation to the number of keyword occurrences. This transformation softens extreme frequency differences, reducing the visual dominance of highly recurring terms without completely diminishing their prominence.

“Actor-Network Theory” appears most prominently, which was expected given its centrality in previous analyses. Its prominence suggests both a theoretical preference and

developing countries enterprise resource planning
 sustainable development project management translation (languages)
 information management philosophical aspects societies and institutions
 human engineering management
 e-learning human computer interaction socio-materialities
 social media information theory circuit theory
 technology transfer research information systems health care
 innovation complex networks ontology
 decision making actor-network theory agential realism
 medical computing social sciences computing e-government
 computer science posthumanism
 knowledge management design information use sociotechnical
 computation theory artificial intelligence postphenomenology
 machine learning information technology structuration theory
 object-oriented ontology information-systems network theory (graphs) technological mediations
 information-technology implementation social networking (online)

Source: Author's elaboration using the Biblioshiny tool.

a consolidated conceptual infrastructure upon which several research agendas rely.

It is noteworthy that terms such as “Postphenomenology” and “Technological Mediations” indicate the significant presence of postphenomenology, especially in studies drawing on Theory of Technological Mediation (Verbeek, 2005b), one of its main strands. The expression “Object-Oriented Ontology” also stands out, pointing to the use of OOO as the primary representative of Speculative Realism in the field. The presence of “Agential Realism” reinforces the inclusion of Agential Realism as a relevant component of the debate.

In addition, the recurrence of IS-related terms, such as “Social Sciences Computing,” “Information Systems,” “Information Technology,” “Artificial Intelligence,” and “Human-Computer Interaction,” highlights the grounding of Entanglement Theories within IS and related domains such as HCI and AI. This suggests that these theories have been mobilized to rethink conceptual foundations, design practices, and the implementation and use of sociotechnical systems. Meanwhile, other terms such as “Information Use,” “Information Theory,” and “Project Management” indicate a pragmatic incorporation of these approaches, particularly in organizational, institutional, and knowledge-management contexts.

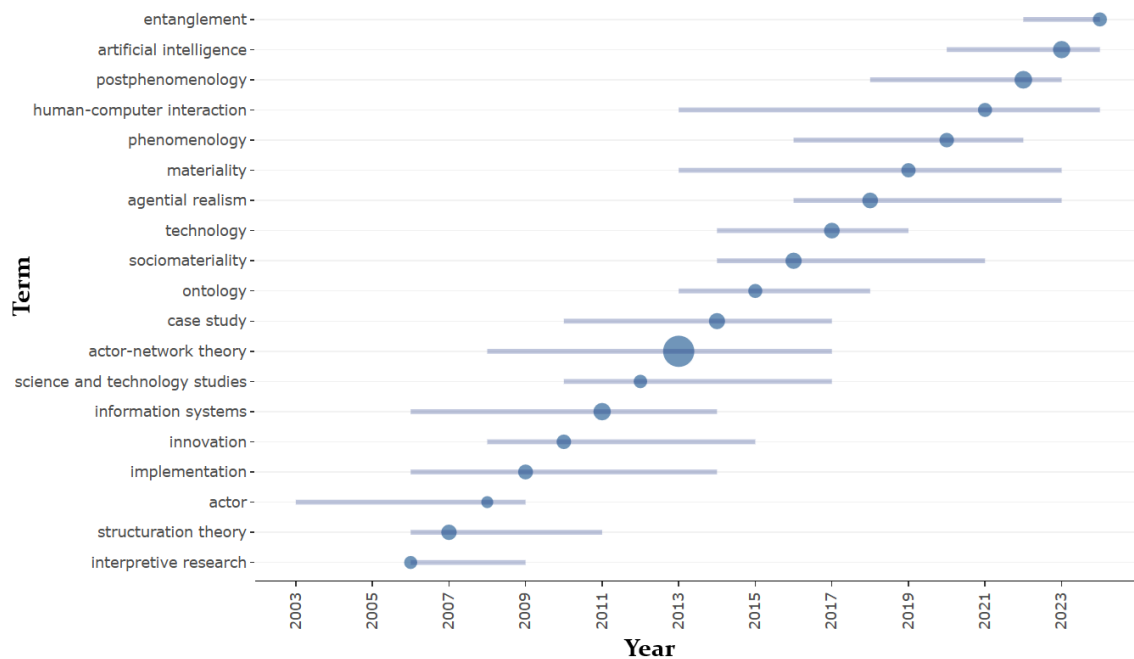
It is also interesting to note the presence of more peripheral and interdisciplinary terms, such as “Health Care,” “Medical Computing,” “E-learning,” and “Standardization,” which point to a movement of thematic expansion. These occurrences suggest that Entanglement Theories are being applied in computing subfields such as medicine, education, and public policy. Along similar lines, the presence of terms such as “Philosophical Aspects,” “Societies and Institutions,” and “Posthumanism” signals the incorporation of more conceptual and critical debates, broadening the reflective scope of the area.

It is important to emphasize that the keyword word cloud reveals only the absolute frequency of terms in the analyzed corpus and does not provide information about their

and reality. This group also connects to contemporary topics such as “ethics” and “artificial intelligence,” indicating an attempt to rethink the foundations of AI from perspectives that view knowledge not as a mere representation of the world but as something constructed within interactions among people, technologies, and contexts.

Although the co-occurrence analysis helps identify central themes and their interrelations, it does not show how these themes evolve over time. To address this limitation, we conducted a temporal trend analysis, presented in Figure 51.

Figure 51: Trending Topics



Source: Author’s elaboration using the Biblioshiny tool.

In the early years of the historical series, terms such as “interpretive research,” “structuration theory,” “actor,” and “implementation” were predominant. These terms reflect an initial focus on methodological foundations, organizational practices, and technology adoption processes. These findings can be correlated with the broader history of the exact sciences, which is deeply intertwined with the modern project of rationalizing the world. Since the Enlightenment, disciplines such as mathematics, physics, and later engineering have become pillars of a scientific ideal grounded in objectivity, predictability, and control (Feenberg, 2008). This paradigm (Park *et al.*, 2020) consolidated a form of scientific reasoning that privileged abstraction and formalization. Within this context, IS emerged and solidified as a disciplinary field strongly influenced by these principles (Ciriello *et al.*, 2024), inheriting a distinctly technicist orientation (Jones, 2018; Rieder *et al.*, 2024) and a reductionist tendency (Malik; Malik, 2021; Selbst *et al.*, 2019). Over time, this logic intensified: the development of software engineering, especially after the so-called “software crisis” of the 1960s (Randell, 1996), deepened the pursuit of formal methods such as mathematical modeling and correctness proofs (Dijkstra, 1976), reinforcing the view of Computing as an exact science oriented toward efficiency and predictability.

Beginning in 2010, a conceptual inflection becomes evident, marked by the

consolidation of “actor-network theory” as a structuring axis of the field. Its peak between 2012 and 2014 coincides with the rise of themes such as “science and technology studies,” “case study,” “ontology,” and “materiality.” This pattern indicates an expanding use of ANT to conceptualize distributed agency, human–non-human relations, and the role of materiality in the constitution of IS.

Between 2015 and 2018, a new theoretical shift emerges, marked by the appearance of terms more closely aligned with contemporary Entanglement Theories and posthumanist approaches. Concepts such as “sociomateriality,” “technology,” “agential realism,” and “materiality” gain prominence and remain influential in subsequent years. This movement reveals a transition from traditional organizational-focused studies to a deeper problematization of relational ontologies and the material conditions of action.

The recent emergence of “entanglement” as a central term represents the most expressive sign of an attempt to consolidate Entanglement Theories in contemporary research. The concept captures, with precision, the growing awareness of the inseparability of humans, artifacts, and sociotechnical practices, while simultaneously acting as an articulating axis for multiple non-anthropocentric theoretical, methodological, and epistemological approaches.

The nearly simultaneous appearance of “artificial intelligence” suggests a promising trend toward integrating AI debates with the perspectives offered by Entanglement Theories. The recent presence of “human-computer interaction” likewise indicates a renewed convergence between these theories and critical HCI studies.

Taken together, this collective movement points to a field undergoing reconfiguration, in which new philosophical and ontological approaches occupy a more prominent position, emerging as alternatives or complements to ANT. The result is a more plural, integrated, and responsive theoretical landscape attuned to the contemporary complexities of sociotechnical ecosystems.

Appendix B

R Script for Integrating Scopus and WoS Data in Biblioshiny

The script (Figure 52) performs the integration and initial preparation of bibliographic data retrieved from the Scopus and Web of Science (WoS) databases for bibliometric analyses. It imports .bib files from both sources, converts them into the format required by the bibliometrix package, merges the two datasets while removing duplicate records, and extracts only the columns relevant for subsequent analysis. It then executes a basic bibliometric analysis, generates a summary of key indicators, and exports the processed data to a CSV file. Finally, it launches the interactive Biblioshiny environment, enabling additional exploratory analyses through a visual interface.

Figure 52: R Code for Data Preparation in Bibliometric Analysis

```
1 library("bibliometrix")
2
3 # definition of the base path, where the Scopus and WoS .bib files are located
4 caminho_base = "C:/Users/55219/Desktop/REFERENCIAL_TEORICO/MAPEAMENTO_EMARANHADO/2025_FEVEREIRO/"
5
6 scopus <- convert2df(paste0(caminho_base,"scopus_0_alterado.bib"), dbsource="scopus", format="bibtex")
7
8 wos <- convert2df(paste0(caminho_base,"wos_0_alterado.bib"), dbsource="wos", format="bibtex")
9
10 # merges both data sources and removes duplicates
11 sw <- mergeDbSources(scopus, wos, remove.duplicated = TRUE)
12
13 write.table(sw, paste0(caminho_base,"dados_bibliograficos_fev_2025.csv"), sep = ";", row.names = FALSE)
14 colunas_desejadas <- c("AU", "DE", "CR", "ID", "C1", "JI", "AB", "RP", "DI", "BE", "BN", "SN", "SO",
15 "LA", "TC", "PN", "PP", "PU", "DB", "TI", "DT", "VL", "PY", "J9",
16 "AU_UN", "AU1_UN", "AU_UN_NR", "SR_FULL", "SR")
17
18 colunas_presentes <- intersect(colunas_desejadas, colnames(sw))
19
20 P <- sw[, colunas_presentes]
21 res <- biblioAnalysis(sw)
22 ds <- summary(object = res, k = 10)
23 write.table(P, paste0(caminho_base,"dados_bibliograficos_fev_2025.csv"), sep = ";", row.names = FALSE)
24 biblioshiny()
```

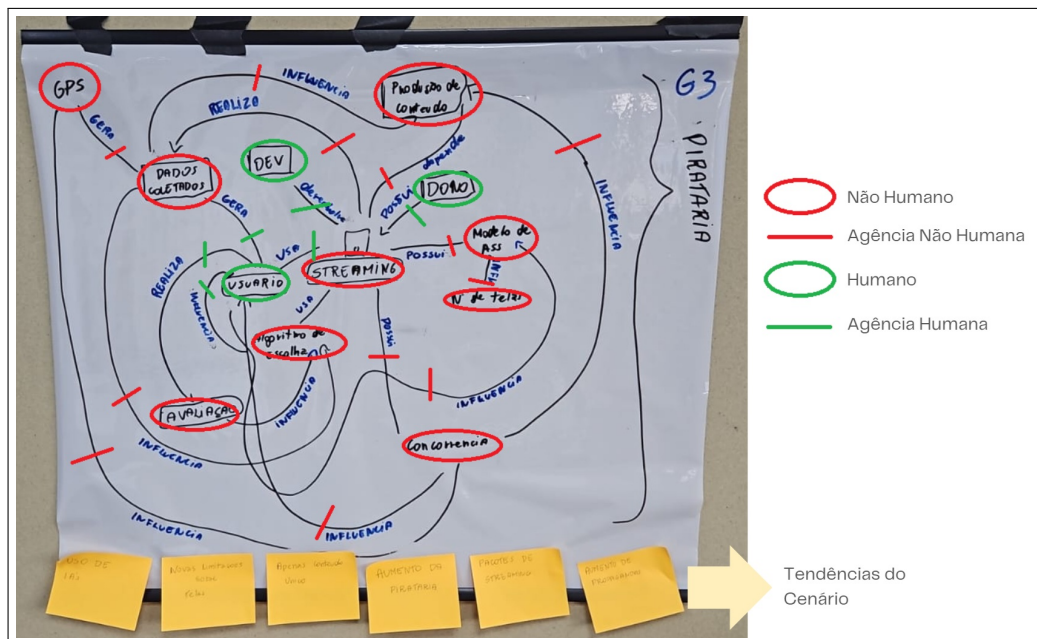
Source: Author's elaboration.

Appendix C

Original Version of the Sociotechnical Board Data Count

Figure 53 presents an example of how the analytical counting of the elements represented on Group 3's Sociotechnical Board was conducted. It identifies the human and non-human actors, as well as their respective agencies. This procedure was applied to all participating groups. By mapping these entities and their relations, the figure provides support for interpreting how participants understood the sociotechnical dynamics of the chosen theme and structured the ecosystem that guided the subsequent speculative stages.

Figure 53: Analytical Counting of the Information from Group 3's Sociotechnical Board (Original).



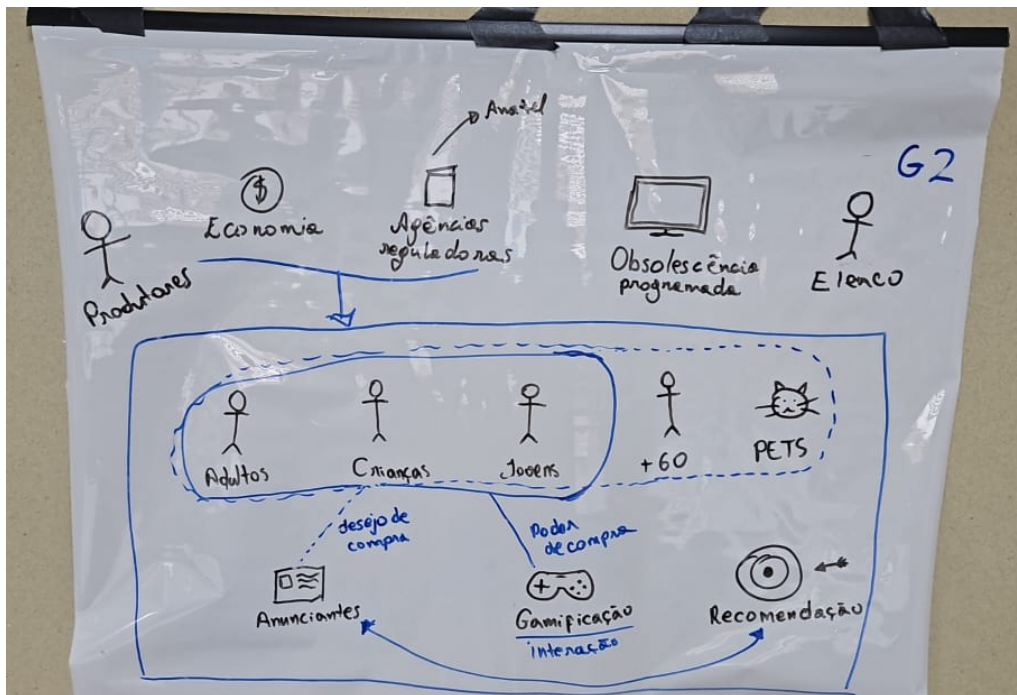
Source: Author's elaboration.

Appendix D

Original Version of Group 2's Sociotechnical Board

Figure 54 shows a photograph of the original material produced by Group 2 during the Speculative Design workshop at IHC 2024. In this activity, the group selected the theme of streaming platforms as their sociotechnical ecosystem. The board captures their initial mapping of human and non-human actors, economic and regulatory elements, algorithmic recommendation mechanisms, and patterns of media consumption associated with this ecosystem.

Figure 54: Sociotechnical Board of Group 2 (Original).



Source: Group 2

Appendix E

Questionnaire administered to the participants of the workshop at IHC 2024

The questionnaire served as a complementary instrument for evaluating the workshop, enabling the identification of how participants understood the concepts presented, perceived the use of the SEF tools, and experienced the proposal of a speculative design approach oriented by post-anthropocentric principles. The responses provided data that supported the analysis of participant engagement, the difficulties encountered, and the formative impacts of the experience, contributing to the empirical validation of the approach developed in the dissertation. Because the dissertation was written entirely in English, the questionnaire was translated from Portuguese, and all participant responses were likewise translated to ensure linguistic consistency and rigor in the presentation of the results.

Speculative Design Workshop

Building Bridges between Technology, Ethics, and Social Inclusion

Informed Consent Form (ICF)

Dear participant,

On October 7th, 2024, you took part in the Short Course *Speculative Design – Building Bridges between Technology, Ethics, and Social Inclusion*, a 6-hour activity conducted by researchers Marcelo Soares Loutfi, Beatriz Ventorini Lins de Albuquerque, Charles Siqueira Xavier, and Sean Wolfgang Matsui Siqueira. This short course is part of Marcelo Loutfi's doctoral research conducted in the PPGI – UNIRIO, and your perceptions about the event are of great importance to us.

We would like to invite you to answer the questionnaire below, which will help us understand your impressions of the short course. Your responses will contribute to the evaluation of the event's results and to identifying opportunities for improvement. We emphasize that the questionnaire is anonymous, and all collected data will be used exclusively for academic and scientific purposes within the context of this research.

We thank you in advance for your participation and valuable contribution.

Sincerely,

Marcelo Loutfi

E-mail: marcelo.loutfi@edu.unirio.br

WhatsApp: (21) 99468-1622

Participant Profile

Indicate your level of knowledge and previous experience with Speculative Design.

5 responses

- **80%** — I did not know about it and have never applied it.
- **20%** — I already knew about it, but have never applied it.
- **0%** — I have applied it a few times.
- **0%** — I have applied it many times.
- **0%** — I have extensive knowledge and experience in the subject.

Indicate your main area of study and/or work

5 responses

- **60%** — Education and Training

- **20%** — Software Development
- **20%** — Other
- **0%** — Requirements Analysis
- **0%** — Business Intelligence (BI)
- **0%** — Project Management
- **0%** — Information Security
- **0%** — Database Administration
- **0%** — User Experience (UX) and User Interface (UI)

Indicate the group you belonged to during the workshop

5 responses

- **20%** — G1
- **40%** — G2
- **20%** — G3
- **0%** — G4
- **20%** — I don't remember

Attention Dimension

What captured your attention the most during the workshop, and why?

This question aims to identify which elements or activities were most engaging, helping to highlight the most impactful aspects of the workshop.

5 responses

1. *I really enjoyed the activity in which we had to envision disruptive technologies and create a story to contextualize the use of the technology for the other groups.*
2. *Watching a design solution being gradually developed from the contribution of each activity carried out. The materials used in the exercises—such as large colorful sheets and post-its—also contributed to my engagement with the content.*
3. *1 — The moments when we classified the implications as desirable/positive/negative and high/medium/low magnitude, because of the different (geometric) shapes used to make this classification.*

2 — The Technological Mediation Cards, because they stimulated creativity in imagining different solutions for the proposed scenarios.
4. *I believe that seeing Speculative Design in practice as a method for exploring possible futures and questioning the ethical and social impacts of technologies was what stood out to me the most.*
5. *I really liked the cards; I found them very creative.*

Was there any moment during the workshop that was particularly surprising or unexpected?

Describe how this influenced your learning experience.

5 responses

1. *The best — and most surprising — moment was the final session, when we had access to the stories and technologies presented by the other groups.*
2. *The brainstorming activity using the Technological Mediation Cards was an unexpected exercise and proved to be surprisingly practical in supporting the developed solutions. Pushing beyond the limits of current technological capabilities and imagining unusual scenarios within the context of the problem was not only fun but also highly enriching.*
3. *I think the presentation stage. At that moment, we had to review all the progress of our idea, and it helped us compile everything we learned and produced during the workshop.*
4. *The discussions on social inclusion and ethics had a strong impact on me... It was interesting to interact with the participants and reflect on these issues.*
5. *I enjoyed the part where we could create the most unimaginable scenarios about the future.*

Relevance Dimension

How do you relate the concepts learned in the workshop to your professional or academic activities?

5 responses

1. *Perhaps a direct relationship with the need that a professor/researcher has to innovate in their professional activities.*
2. *The concepts learned expand the knowledge base necessary for software development activities. They help in considering the current scenario of a given application, identifying relationships and stakeholders, and contributing to a comprehensive analysis that supports the development of creative and context-appropriate solutions.*
3. *It is relevant to my field because I work with interface development (prototyping) in my research group.*
4. *The approach can enhance my ability to anticipate challenges and create projects that are more aligned with human needs and with the impacts that may arise in the medium and long term.*
5. *Collaborative work, collective thinking...*

In what way did the workshop address issues that are important to you in your field of work?

5 responses

1. *I believe that our group tries to incorporate aspects of diversity and inclusion into the solutions we envision, and although this topic was not the main focus of the workshop, the way the activities were conducted allowed us to explore it.*
2. *By presenting strategies for conceiving innovative ideas while considering market trends.*
3. *By making us stop to think about the implications—both positive and negative—of the products we develop.*
4. *I believe that speculative design challenging conventional assumptions and exploring alternative futures was a very important aspect for me. The provocative scenarios developed during the workshop and the narratives were interesting in helping us reflect on our own practices.*
5. *When imagining scenarios, these scenarios can be of any nature; therefore, the approach is viable in any field of work.*

Confidence Dimension

What skills or knowledge acquired during the workshop do you feel confident applying? And which ones do you feel you need more support with?

5 responses

1. *I believe I need more rounds of the workshop to feel confident applying the proposed speculative design technique. There are many steps.*
2. *I feel confident sharing the general idea of the Speculative Design framework presented, especially the sections on analyzing the current scenario, identifying the involved agents and their relationships, observing trends, and recognizing implications. The areas where I would need more support are sociotechnical analysis and the consolidation of the obtained results to conceive a concrete solution based on the defined timeframe.*
3. *I feel confident applying the concept of involved agents and the implications of trends (including their classification).*
4. *I believe I need more support to identify the trends themselves and to explore the Technological Mediation Cards without drifting too far from the initial project.*
5. *I feel confident applying the techniques for constructing speculative scenarios, bringing them into practice to imagine alternative futures and explore the ethical and social implications of technologies. But I still need to delve deeper into applying speculative design frameworks in real and complex contexts... this was my first “interaction” with Speculative Design.*

After participating in the workshop, how do you assess your ability to contribute to discussions or projects involving speculative design?

5 responses

1. *I believe it broadened my mind regarding the possibility of imagining new technologies. I think that in a master's program, a PhD, and scientific research in general, we are often required to stay very grounded.*
2. *I believe I now have enough knowledge to understand the foundations of discussions or projects and contribute with ideas based on the concepts learned throughout the workshop.*
3. *I believe I now have enough knowledge to understand discussions involving the topic, and it can especially help me incorporate speculative design into my own projects.*
4. *I recognize that I still need more experience... learning more about the subject and how to apply it in real projects.*
5. *Moderate. I still have a lot to learn, but I would love to participate in more speculative design workshops.*

Satisfaction Dimension

What did you value the most in the workshop, and what do you think could be improved to increase participant satisfaction?

5 responses

1. *The group interaction was the highlight of the workshop. Regarding improvements, I think there could have been more time to carry out the activities. It was very rushed.*
2. *I really appreciated the practical moments, all directly related to the content presented. One thing that could be improved is the amount of time dedicated to each activity, which turned out to be short on some occasions.*
3. *What I valued most were the tools presented, such as the model for building the ecosystem, the charts for classifying implications, and the technological mediation cards.*
4. *What could be improved is perhaps explaining more clearly at the beginning of each step how it connects to the previous one. I felt I had some difficulty with this during the presentation.*
5. *I loved the practical and reflective approach — the dynamic encouraged interaction among participants, creativity, and critical thinking. I would have liked to see practical examples of applying speculative design in different contexts, such as real projects in companies or organizations (although I know time was limited). I think everything went very well.*

Would you recommend this workshop to a colleague or friend? Please explain your answer, including what would make you more or less inclined to recommend it.

5 responses

1. *Yes. I found it important for helping us think outside the box, but in a structured way.*
2. *Yes, I would recommend the workshop to a friend interested in the HCI field. The reproduction of the activities with a little more time would make me even more inclined to recommend it, unlike a purely theoretical approach, which would make me less inclined.*
3. *Yes, I would recommend it mainly to friends who study or work in the design field.*
4. *Yes, I would recommend it! I like the creative and reflective approach on the ethical and social impact of technologies. The practical dynamics made learning engaging and applicable, especially for those working with innovation. It was an enriching and inspiring experience.*
5. *Yes. In the healthcare field, it is necessary to think about ways to serve a very diverse audience with information and services. My friends in health research would enjoy this approach to imagining new ways of doing their work.*