PROCESS-ORIENTED AI:

ARTIFICIAL INTELLIGENCE FOR A CONNECTED WORLD

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Preface

This dissertation is presented in a multimodal format that combines a written manuscript with supplementary digital materials. The written manuscript develops the theoretical and philosophical arguments in this research, and the multimodal component presents the accompanying maps discussed in chapters 4 and 5. These maps, developed alongside the theoretical exploration, offer an exploratory guide to creating with AI through a process-oriented approach.

The multimodal component consists of 9 files, which include diagrams and conceptual maps discussed in the theoretical chapters. These files represent a process-oriented framework for designing an AI system that allows for relationality and incorporates social and environmental context into an AI project. The multimodal components are designed to complement the written analysis. However, they can be used separately as an experimental approach to create AI through a process-oriented framework explored in this research.

Abstract

With the advancement of AI, using this technology to solve life challenges has become a real possibility. However, AI systems are laden with bias and often perpetuate old prejudices and injustices. To step beyond such limitations requires a leap outside the field to allow for a fresh perspective on its design. This dissertation looks at AI challenges through the lens of Alfred North Whitehead's process philosophy to imagine AI design beyond its current state of development. The power of philosophy lies in its ability to bypass habitual perception and gain a fresh perspective.

This dissertation draws on process philosophy to develop a theoretical framework for a dynamic AI design that incorporates a multidisciplinary approach and more closely reflects human thinking. Key research questions addressed in this process are: What principles in Whitehead's philosophy can be applied to AI? How can they be integrated into AI components, such as data and machine learning? Furthermore, what are the implications of designing AI systems through a process philosophy lens? How do these changes make a process-oriented AI different from traditional AI systems? How might this influence the relationship between humans and AI? Finally, how can complex technical ideas in this research be communicated without oversimplification or loss of detail? What are the possibilities of bridging communication gaps among disciplines?

The process-oriented AI system presented in this dissertation offers a dynamic design approach that influences and adapts to its environment. Rethinking AI design within the process philosophy framework involves taking gradual steps to combine empirical science with human stories, culture, and art. The outcome is a creative process involving human experts, who hold the domain knowledge, and a machine that is responsive to feedback and can efficiently interpret

large amounts of information. This approach blends the quantitative analysis of what is happening with a more nuanced and complex view of why it is happening. The result is a co-creation, reconfiguration process that requires adjustment and collaboration, guided by human agents throughout its discovery.

Acknowledgments

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Chapter 1: Introduction

When I moved to my neighbourhood in the north of Toronto, our half-century-old house was surrounded by large trees. A few steps down the street, a lush marshland welcomed foxes into its grassy fields and invited storks to its quiet streams. Throughout the year, cardinals and blue jays visited the trees around my house. But within a few years, all this disappeared. A developer moved in and turned the marshland into rows of townhomes, causing many who disliked the changes to move out. New neighbours cut down the trees to make space for gazebos and other outdoor living areas. Within a decade, the old grassy, tree-filled oasis was gone, and no one seemed to care. Despite growing research that establishes a direct link between green space and human well-being, there is a deep disconnect between daily life and nature.

Working in the software industry for years, I originally planned to create a social app focused on the importance of maintaining access to nature in urban centres. This app would use AI and simulation to raise awareness about the role of green spaces in cities and increase public consciousness about the beneficial effects of green spaces. However, looking critically at the process of creating this app using AI opened numerous challenges. By using AI to enhance social wellbeing, I hoped to build on a platform of fairness and inclusivity.[1] Yet, once I began the work, I realized that an AI system would forever ignore the context and remain static, inaccurate, and limited in its capacity. The inability of current AI systems to account for the dynamic nature of life and to include different perspectives results in recurring ethical challenges. Given these limitations, I recognized that applying a traditional AI approach to a project with overlapping

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[1] Nenad Tomašev et al., "AI for Social Good: Unlocking the Opportunity for Positive Impact," *Nature Communications* 11 (2020), https://doi.org/10.1038/s41467-020-15871-z.

complexities involving nature, wildlife, and diverse communities would make it difficult to achieve a fair and inclusive outcome.

“The medium is the message,” Marshal McLuhan’s famous quote, applies directly to AI for problem-solving in complex scenarios. Thus, the central question of my project became: How could we reach a fair outcome using an inherently biased medium? With that in mind, what started as building a platform using AI turned into a quest to find a framework for working with technology to ensure that context, different voices, diverse players, and fairness were represented in the system. As a result, instead of making the app, I put together a theoretical framework that facilitated working with the technology in a way that accounted for context.

To achieve this, I turned to the philosophy of Alfred North Whitehead to find a conceptual framework for working with AI that reflected the interconnected nature of complex problems and offered more opportunities for fairness and inclusivity. As part of this dissertation, I also created a product design for the SproutCityTO app that I originally had in mind. The product design thus functions as a case study to test the theoretical framework, apply it to real-world scenarios, and provide guidance for developing a future app that incorporates these variables.

Framing of AI

The term AI is often used to describe a type of Artificial Intelligence that requires large computing infrastructure and necessitates a massive amount of data to operate. However, relying on this definition of AI as a resource-hungry system doesn’t define the possibilities in creating with AI technology. For instance, the directions toward TinyML or Small AI reveal a different set of possibilities for AI technology that rely on smaller resources while creating systems that could be more accessible and are more frugal in their use of computational power. Bringing AI outside of its marketing and commercial context and rethinking AI in this frame allows this dissertation to re-evaluate and reconsider its use and possible impacts.[2]

The Problem with AI

Most AI projects look at technology as a tool to address human needs and challenges. However, not all real-world circumstances can be reduced to straightforward experiments. For example, working with AI demands isolating data from a limited timeframe to represent the entire reality of the scenario and further simplifying the environmental variables to increase efficiency. When facing challenges, an AI system typically narrows its focus and ignores the context. To put it differently, creating a traditional AI system to improve the relationship between humans and nature means using an anthropocentric system, with mankind at the center of everything. Moreover, this system identifies patterns in information that represent a static and isolated snapshot of a complex, dynamic reality. As a result, the outcome disregards cultural values or the history of the land and the city's development. But what if the cultural or historical context is important in making decisions? Could more data add context to improve decision-making?

In February 2024, Google DeepMind introduced Gemini 1.5, its next generation of large language models to process one million tokens simultaneously. Tokens provide information such

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[2] S. Soro, "TinyML for Ubiquitous Edge AI," *ArXiv*, February 2, 2021, https://www.semanticscholar.org/paper/TinyML-for-Ubiquitous-Edge-AI-Soro/6adc520e425251b78fc8d85f5c8f8b091f8b8c5d; Lindsey Wilkinson, "Why Enterprises Are Turning to Small AI Models | CIO Dive," 2025, https://www.ciodive.com/news/small-language-models-AI-LLMs/740281/; Sangbu Kim and Christine Z. Qiang, "Small AI, Big Impact: Harnessing Artificial Intelligence for Development," World Bank Blogs, 2025, https://blogs.worldbank.org/en/voices/small-ai-big-impact-harnessing-artificial-intelligence-for-development.

as text, videos, and images that are used as context windows. A context window determines the amount of content summarized within a given prompt. AI technology is expanding and the amount of information that can be processed is growing continuously.[3] However, despite the rise in data availability, AI remains far from equal to human reasoning and judgement. AI, by design, simplifies data and removes contextual relationships such as the environment, time, location and the living experience to shorten its processing time. Equally, AI algorithms are reductionist and ignore complexities for efficiency. It should be noted that AI development is changing incredibly rapidly, and my work here reflects the knowledge and state of AI during the development of this dissertation from 2022 to 2025.

Where Are We Going from Here?

In the 1960s, AI researcher Philip Agre was critical of progress in AI and suggested rethinking its design. However, it was too late. The momentum for AI development had already been set.[4] Today, AI development has made such long strides that considering a complete re-evaluation of its design is not feasible. Thus, my aim here is not to reinvent an AI system but to create a set of practical protocols to work with existing AI technology and address its limitations in understanding context and real-world complexities.

This framework allows for an AI system that is incremental in its learning process and responsive in its output. My goal in creating this system is to lay the groundwork for working with AI to make the system context-aware, dynamic, and responsive to cultural, personal, and

[3] Sundar Pichai and Demis Hassabis, "Our Next-Generation Model: Gemini 1.5," Google, February 15, 2024, https://blog.google/technology/ai/google-gemini-next-generation-model-february-2024/; "Long Context | Gemini API," Google AI for Developers, accessed May 15, 2025, https://ai.google.dev/gemini-api/docs/long-context.

[4] Philip E. Agre, "Toward a Critical Technical Practice: Lessons Learned in Trying to Reform AI," 1997, 27, https://pages.gseis.ucla.edu/faculty/agre/critical.html.

historical values. To achieve this, I step outside the boundaries of conventional AI design and re-imagine its role in decision-making, envisioning new possibilities for the technology.

How Do We Reach This Objective?

Most technological solutions for improving AI are limited by technical and economic constraints. To evaluate and offer a working system that can integrate AI into complex real-world scenarios, we need to step outside the limitations of the technology. I approach this by looking at AI through a different discipline.

This requires examining the technology from a self-reflective field of knowledge that allows for seeing beyond its current state. The answer lies in finding a philosophical system concerned with empiricism, practicality, relationality, and adaptability in order to investigate AI critically and to re-imagine its possibilities.

To this end, I approach philosophy through a pragmatic lens and as an "instrument" that can help to solve AI challenges. This re-evaluation of technology allows the AI design process to move beyond its technical limitations, allowing us to view it from a perspective that aligns more with its ideal potential rather than its current state of disconnectedness and abstraction. An Indigenous epistemological approach to science, assemblage theory, Actor-Network Theory, and process philosophy could each offer different ways of looking at AI as a tool in an interconnected web of events and happenings.

The Indigenous epistemological view, for example, could lead to studying AI through its relational perspective. This critical approach to the scientific method in support of values, spirituality, or communal responsibilities could unlock new avenues in engaging with AI. Robert Regnier questions the place of Western science using Alfred N. Whitehead and emphasizes the need for values, balance and interconnectedness at the heart of the scientific process.[5] Likewise, Indigenous research methodologies such as Shawn Wilson's three principles of respect, relationality, and reciprocity can facilitate learning about AI through interconnectivity.[6]

An alternative strategy for rethinking AI is the assemblage theory. The assemblage theory offers a holistic framework to move beyond the static nature of AI by emphasizing change and studying the connected parts of the system for creative possibilities.[7]

Another viable method is the Actor-Network Theory (ANT). John Law saw ANT as a way to describe the dynamics in the sociology of science and technology and paved the way for learning about "knowledge" through the network of its different parts.[8] Later, Bruno Latour expanded the theory to equate the agency of both the human and non-human actors in this network. With its focus on technology, the ANT framework could offer pathways to grasp AI through its mutual influences on society and socio-technical dynamics. In the same way, ANT offers a framework to understand AI through context and inter-relationality for analyzing the dynamic between broader systems and allows for insight into the human and AI relationship.[9]

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[5] Robert Regnier, "Bridging Western and First Nations Thought: Balanced Education in Whitehead's Philosophy of Organism and the Sacred Circle," *Interchange* 26, no. 4 (1995): 383–415, https://doi.org/10.1007/BF01434743.

[6] Jennifer Grenz, *Medicine Wheel for the Planet: A Journey toward Personal and Ecological Healing* (Knopf Canada, 2024), 47. Other sources: Shawn Wilson, *Research Is Ceremony: Indigenous Research Methods* (Fernwood Publishing, 2008).

[7] Christopher Hanley, "Thinking with Deleuze and Guattari: An Exploration of Writing as Assemblage," *Educational Philosophy and Theory* 51, no. 4 (2019): 413–23, https://doi.org/10.1080/00131857.2018.1472574.

[8] John Law, "Notes on the Theory of the Actor-Network: Ordering, Strategy, and Heterogeneity," *Systems Practice* 5, no. 4 (1992): 379–93, https://doi.org/10.1007/BF01059830.

[9] Scott H. Hawley, "Challenges for an Ontology of Artificial Intelligence," arXiv:1903.03171, preprint, arXiv, February 25, 2019, 13, http://arxiv.org/abs/1903.03171.

Accordingly, ANT could provide an effective framework for exploring ethical issues around Generative AI in content creation or rethinking the idea of enhanced intelligence.[10]

Another possibility, which is the focus of this research, is the process philosophy of Alfred North Whitehead. Whitehead's philosophy offers a pragmatic model for understanding reality that is rooted in empirical reasoning. What makes process philosophy unique, however, is its emphasis on creativity and its role as the engine beneath the evolutionary nature of the universe. This perspective offers an approach to guiding AI design that is built on transformation and adaptability. Process philosophy suggests seeing "things not as they are but how they undergo change."[11] The emphasis on creativity and change is valuable for understanding and developing AI technology. To put it differently, viewing AI through the lens of transformation could lead to the creation of systems that are more adaptable, responsive, and dynamic in their interactions. This is crucial in understanding an evolving new technology that can account for novel changes or consequences of previous decisions.

While Indigenous epistemology, the assemblage theory and ANT could offer relationality and holism in understanding AI technology, I chose to work with the process philosophy of A.N. Whitehead for its explicit focus on creativity and empirical science. In this context, process philosophy not only offers a critical lens to understand the place of AI within our society but also offers a unique way to re-imagine AI design through a creative lens.

Addressing urban ecological challenges with AI using this theoretical framework can take into account evolutionary complexities. Therefore, I chose Alfred N. Whitehead's process

[10] "An Ethical Study of Generative AI from the Actor-Network Theory Perspective," SciSpace - Paper, February 28, 2024, https://doi.org/10.5121/ijci.2024.130106; Noel Carroll, "Augmented Intelligence: An Actor-Network Theory Perspective," *ECIS 2021 Research Papers*, June 14, 2021, https://aisel.aisnet.org/ecis2021_rp/37.

[11] Hawley, "Challenges for an Ontology of Artificial Intelligence," 13.

philosophy to inform a theoretical framework for guiding AI design. Design through the lens of process philosophy encourages seeing AI as a dynamic system that interacts with its environment, adapts over time, and accounts for the knowledge embedded in the lived experience, culture, and history.

Why Research-Creation?

This dissertation approaches process philosophy as an "instrument" to create a conceptual framework and inform a dynamic AI design. Whitehead's philosophy values the role of science but emphasizes relationality and the importance of imagination in research and investigation. In *Process and Reality*, Whitehead emphasizes the role of creativity as a discovery method and writes that "the true method of discovery is like the flight of an aeroplane. It starts from the ground of particular observation; it makes a flight in the thin air of imaginative generalization; and it again lands for renewed observation rendered acute by rational interpretation."[12]

An effective methodology to apply a philosophical and conceptual framework to AI must go beyond data-gathering or applying existing philosophical theories to AI. This methodology should start from a scientific ground and take an imaginative turn to discover novel possibilities in AI design, and finally land on the practical part of the technology. Following this method, the "imaginative" process can open doors to move beyond the theoretical and technical and reach novelty in finding solutions.

The creative act is a relational process between the artist's experience, conceptual ideas, and objective observations. Through this method, the artist's knowledge, lived experience,

[12] Alfred North Whitehead, *Process and Reality: An Essay in Cosmology*, Corr. ed, ed. David Ray Griffin and Donald Wynne Sherburne (The Free Press, 1978), 5.

philosophical principles, and information about AI are fused to form new knowledge. This process of refinement and transformation creates new insights that will not be accessible without combining research with the creative act. Owen Chapman and Kim Sawchuk define research-creation as an approach "that incorporates creative processes and involves the production of artistic works in academic programs."[13] Research creation is a process of 'becoming entangled in relations.'[14] Here, this entanglement ties AI technology, process philosophy, and creative practice to form a conceptual framework for designing AI systems.

In *Towards more-than-human digital data studies: developing research-creation methods*, Deborah Lupton and Ash Watson write that "research-creations are directed towards creating different worlds and imagining novel futures." Likewise, my research-creation methodology aims to find novel approaches to inform AI design by making it more context-aware and dynamic in relation to its environment.

To develop this research creation approach, I incorporate theoretical analysis, concept mapping, data visualization, and digital product design. This involves two steps: first, I create a theoretical framework for guiding AI design based on process philosophy by using data visualization and concept mapping. Second, I develop a case study in the form of a holistic digital product design for a web application named SproutCityTO. SproutCityTO is a web application with an AI core based on process-oriented design principles that aims to increase public awareness of the link between heating urban centers and global warming. SproutCityTO is

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[13] Owen B. Chapman and Kim Sawchuk, "Research-Creation: Intervention, Analysis and 'Family Resemblances,'" *Canadian Journal of Communication* 37, no. 1 (2012), https://doi.org/10.22230/cjc.2012v37n1a2489.

[14] Deborah Lupton and Ash Watson, "Towards More-than-Human Digital Data Studies: Developing Research-Creation Methods," *Qualitative Research* 21, no. 4 (2021): 463–80, https://doi.org/10.1177/1468794120939235.

a practical and approachable case study of a process-based AI app that encourages environmental stewardship.

This dissertation applies process philosophy to elements of AI design to identify process principles that can aid in improving AI technology. Second, it uses concept mapping to apply these theoretical principles and explores their validity and applicability in guiding the AI design process. The iterations of “thinking–making–doing”[15] refine the theoretical framework to an applicable outcome. Here, the conversation between the concept mapping process and the theoretical principles refines the conceptual framework to a more practical model. The concept map explores the validity of the theoretical framework by exemplifying the life and story of a single plant in an urban park. The relational and visual approach to philosophy and AI integrates these modes of knowledge and makes the outcome more engaging and approachable. This method bridges the gap between Whitehead’s philosophy and AI technology.

To summarize, the research-creation approach incorporates the interconnected nature of process philosophy and finds its way through identifying relationships between different modes of knowledge. This integrates AI into a larger epistemological map that integrates human life, nature, philosophy, and social relations.

The concept map direction used in this dissertation is inspired by two creative works: Kate Crawford and Vladan Joler’s *Anatomy of an AI System,* which was exhibited at MOMA in 2018, and Vladan Joler and Matteo Pasquinelli’s *AI as Instrument of Knowledge Extractivism*.[16] Both projects respond to the complex technicality of AI and its relationship to a larger social life.

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[15] Stephanie Springgay and Sarah E. Truman, “Walking Methodologies in a More-than-Human World: WalkingLab,” Routledge & CRC Press, 2018, https://www.routledge.com/Walking-Methodologies-in-a-More-than-human-World-WalkingLab/Springgay-Truman/p/book/9780367264956.

[16] Vladan Joler and Matteo Pasquinelli, “The Nooscope Manifested,” *Fritz Ai*, 2020, https://fritz.ai/nooscope/; Kate Crawford and Vladan Joler, “Anatomy of an AI System,” Anatomy of an AI System, 2018, http://www.anatomyof.ai.

Both works demystify the inner workings of complex systems. Their visual language creates a balance between simplicity and complexity in communicating technical ideas by engaging the audience in an intricate set of visual designs and illustrations. Like these artists, my concept mapping process refines ideas and offers an effective platform for visually communicating the theoretical framework. This is important, since Whitehead's process philosophy and AI technology are highly technical fields, and bridging the communications gap is an important part of this multi-disciplinary research.

Novel Contributions

As explored earlier, current AI development faces significant challenges, such as bias, ignorance and detachment from the interconnected reality of social, historical and natural phenomena. Using Whitehead's process philosophy as a conceptual framework offers a unique solution for reintroducing context-awareness and ethics into AI design and development. The research-creation methodology also integrates different fields of knowledge into a cohesive system and presents it in a way that engages the intended audience.

The unique contribution of this dissertation is using process philosophy to inform AI design, and shift AI from a static and isolated system to a dynamic and responsive system that is context-aware and ethically grounded. This framework redefines the relationship with AI as a co-creator and a collaborator, rather than as an autonomous system. Moreover, it offers solutions for implementing this partnership and sustaining this continuous collaboration. The co-creation process establishes protocols to transfer human reasoning to the machine, such as common-sense thinking and knowing through lived experience. Working through continuous learning, this co-creative procedure will ultimately lead to creative and novel solutions in solving real-world problems.

Intended Audience

Process-oriented AI design is a strategy for solving complex problems that requires sensitivity to a diversity of players, their context, and historical or cultural backgrounds. AI technology has come a long way from its early days when it was confined to supercomputers in university laboratories or large institutions. Today, advancements in hardware and software have made AI more accessible. Currently, anyone with a laptop can sit in a coffee shop and create an AI application on the cloud. Consequently, individuals from outside mathematics and computer science explore the potential and possibilities of using the technology in their own practices.

There is a growing trend among artists from diverse backgrounds to use technology as a tool that informs their creativity. For instance, Jenna Sutela uses AI and machine learning to create sculptures and media installations.[17] Refik Anadol, a Turkish American artist, creates immersive installations and uses machine learning to establish visually provocative data visualizations.[18] Similarly, Ross Goodwin collaborates with AI to create installations and write screenplays.[19] As a medium, AI can expand the creative act to solve real-world challenges and collaborate with other disciplines.

A broad set of professionals incorporate AI in their practice, from artists and medical practitioners to geologists, sociologists, urban planners, and engineers. However, among these,

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[17] Jenna Sutela, “Jenna Sutela,” 2025, https://jennasutela.com/.

[18] Refik Anadol, “Refik Anadol,” 2025, https://refikanadol.com/.

[19] “Ross Goodwin – Artist Profile (Photos, Videos, Exhibitions),” AIArtists.Org, accessed August 30, 2024, https://aiartists.org/ross-goodwin.

artists occupy a special place. Artists are often curious about their process and self-reflective about their art. This means that they are more likely to ask questions about the role of technology and its relationship with their work.

Canadian media philosopher Marshal McLuhan viewed artists as “the antennae of the race” or visionaries who anticipate future social and technological changes. He saw artists as able to foresee future challenges much earlier than the rest of society. This means that artists using AI have a unique place and ability to explore the technology beyond its current limitations, since they are open to rethinking the technology outside its conventional structure. Similarly, having a natural tendency towards openness and creative thinking makes them more likely to engage with the philosophical aspect of their work and contemplate the role of the medium in their practice. This translates to more willingness to examine AI through a process-oriented framework.[20]

Research Questions

This dissertation uses process philosophy to create a theoretical framework to inform a dynamic AI design. Key research questions addressed in this process are: What principles in Whitehead’s philosophy can be applied to AI? How is it possible to integrate them into AI components such as data and machine learning? Furthermore, what are the implications of designing AI systems through a process philosophy lens? How do these changes make a process-oriented AI different from traditional AI systems? How does this change the relationship between humans and AI? And finally, how is it possible to communicate complex technical

[20] Wolfgang Muench, “Men of Letters: Perspectives on Multisensory Environments in the Hall-McLuhan Correspondence, 1961–1977,” *Leonardo* 57, no. 3 (2024): 334–39, https://doi.org/10.1162/leon_a_02529.

ideas in this research without oversimplification or sacrificing details? What are the possibilities for bridging communication gaps among disciplines?

Dissertation Structure

Chapter 1, the current chapter, introduces the concepts in this dissertation and examines the plan, the direction of the research, and its ultimate objectives.

Chapter 2 covers the relationship between Alfred N. Whitehead's process philosophy and Artificial Intelligence. The chapter discusses elements of AI, such as data and machine learning, and lays down the technical and historical groundwork for discussing design with AI in later chapters. Chapter 2 also examines the philosophical principles in process philosophy to establish the background and terminologies. Moreover, it defines the connections between AI and process philosophy and assesses how a philosophical approach can benefit a technological system.

Next, chapter 3 lays down the methodology of this dissertation. Developing the right method to address the multidisciplinary aspect of this dissertation requires a process that can address the creative and multidisciplinary nature of this project. Part of the work toward my dissertation has been finding the right methodological approach and realizing a creative path to build knowledge and communicate ideas through a visual language without sacrificing the depth of information and complexity of the material in different fields involved. This direction, which bridges the gap between the theoretical and technical sides, strongly influences the choice of this methodology. Thus, Chapter 3 explores the inner workings of this approach and how it fits into the theoretical and technical aspects of the research-creation.

Chapter 4 proposes a theoretical framework for creating process-based design using six principles, linking the elements of Whitehead's philosophy to AI systems. The chapter proposes a set of measures that can be implemented in an AI system to incorporate characteristics such as interconnectivity and dynamism into its design. In process philosophy, knowledge is not static. Rather, it is accumulated through integrating and transforming information from different fields and experiences. This knowledge is continuously evolving and interacting with other players in the system. Bringing together different knowledge domains in philosophy and computer science, this chapter adopts a visual language to lay down the relationships and define the principles of a PAI system. Laying down the framework using an example, this chapter visualizes the connection between data, machine learning models, and the nature of human interaction in this system. Furthermore, Chapter 4 covers the PAI concept maps and lays down the theoretical framework for designing AI within process philosophy.

Reaching for integrated knowledge and adopting a pragmatic design are key to translating the process-oriented theoretical framework in Chapter 5. This chapter gives a practical dimension to the theoretical ideas and uses the SproutCityTO as a case study to create a holistic product design that exemplifies the use of this conceptual framework. The SproutCityTO web app uses AI to analyze the relationship between humans and nature in Toronto and promotes various activities to improve and enhance relationships between humans and nature, while raising public consciousness about the importance of tree canopies and nature in tackling climate change.

Chapter 6 concludes by reflecting on the process and challenges of creating an AI based on Whitehead's process philosophy. Placing the right tools and protocols for human-AI collaboration under the process framework can integrate the human experience into an AI system. This means we can develop AI systems that are committed to ethical considerations and are equally sensitive to values and nuances of social and cultural life.

Chapter 2: Whitehead and AI

In this chapter, I establish the theoretical, philosophical, and technical background required for this dissertation. I start by examining AI through some of its social and technical problems. Understanding these shortcomings allows us to narrow philosophical ideas into principles that can guide AI design and give us the tools and knowledge required to re-evaluate AI design through process philosophy.

Initially, I explore the foundation for AI and critically examine its roles, abilities and shortcomings. This helps to identify key deficiencies and allows us to rethink AI design through the process philosophy framework. Likewise, I examine Whitehead's philosophy process and its relationship to AI design. Finally, I investigate the intersection of AI and process philosophy and conclude with guidelines and design principles in later chapters.

AI Troubles

Artificial intelligence is celebrated by many as the most revolutionary technology in human history. Andrew Ng, an AI scientist at Stanford University, calls AI "the new electricity."[21] The technology strives to simulate human behaviour and is expected to give us the ability to solve difficult and time-consuming problems, such as those in education, healthcare, judicial systems and transportation. However, the hype around AI has obscured its real abilities by overpromising what could be achieved. When IBM launched Watson Health, it aimed to revolutionize healthcare and provide personalized medicine based on medical records and data. Unfortunately, the multi-billion-dollar project came to a quick halt as it couldn't deliver proof of

[21] Andrew Ng, "Why AI Is the New Electricity," Stanford Graduate School of Business, 2017, https://www.gsb.stanford.edu/insights/andrew-ng-why-ai-new-electricity.

concept.[22] AI washing, a phenomenon recognizable when companies exaggerate AI capabilities, has led the public to overestimate the true worth and nature of AI. [23] This has distorted public perception of the technology and obscured both its real abilities and shortcomings.

From a practical perspective, AI has numerous problems. It creates an exorbitant carbon footprint to manufacture hardware and maintain its computing infrastructure.[24] At the same time, AI lacks transparency and often perpetuates the status quo by amplifying biases and discrimination. It raises privacy concerns and fails to understand ethical and moral values.[25] Ruha Benjamin, the author of *Race After Technology*, describes how new technology makes the "gap between egalitarian principles and inequitable practices" much subtler in their discrimination.[26]

As is often the reality, marginalized and underrepresented populations are most frequently caught in unjust scenarios that result from AI bias. For instance, they might be denied

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[22] Todd R. Weiss, "IBM Watson Health Finally Sold by IBM After 11 Months of Rumors," AI Wire, 2022, https://www.aiwire.net/2022/01/21/ibm-watson-health-finally-sold-by-ibm-after-11-months-of-rumors/; Eliza Strickland, "Layoffs at Watson Health Reveal IBM's Problem With AI - IEEE Spectrum," 2018, https://spectrum.ieee.org/layoffs-at-watson-health-reveal-ibms-problem-with-ai; Leila Hawkins, "IBM Watson Health Was Always Going to Struggle," February 23, 2021, https://healthcare-digital.com/technology-and-ai/ibm-watson-health-was-always-going-struggle; Paul Kunert, "IBM CEO Explains Why Company Offloaded Watson Health," 2022, https://www.theregister.com/2022/06/08/ibm_ceo_arvind_krishna_explains/.

[23] Katie Collins, "AI Fatigue Is Wearing Me Down. The Hype Obscures What We Really Need to Know - CNET," 2025, https://www.cnet.com/tech/services-and-software/ai-fatigue-is-wearing-me-down-the-hype-obscures-what-we-really-need-to-know/; Bernard Marr, "Spotting AI Washing: How Companies Overhype Artificial Intelligence," Forbes, 2024, https://www.forbes.com/sites/bernardmarr/2024/04/25/spotting-ai-washing-how-companies-overhype-artificial-intelligence/; Hanan Al Haddi, "AI Washing: The Cultural Traps That Lead to Exaggeration and How CEOs Can Stop Them | California Management Review," California Review Management, 2024, https://cmr.berkeley.edu/2024/12/ai-washing-the-cultural-traps-that-lead-to-exaggeration-and-how-ceos-can-stop-them/.

[24] Keith Kirkpatrick, "The Carbon Footprint of Artificial Intelligence," *Communications of the ACM* 66, no. 8 (2023): 17–19, https://doi.org/10.1145/3603746.

[25] Bernard Marr, "The 15 Biggest Risks Of Artificial Intelligence," Forbes, 2023, https://www.forbes.com/sites/bernardmarr/2023/06/02/the-15-biggest-risks-of-artificial-intelligence/.

[26] Ruha Benjamin, *Race after Technology: Abolitionist Tools for the New Jim Code* (Polity, 2019), 26.

a loan, miss out on job opportunities, be flagged as a criminal on CCTV footage, or be discriminated against by social and criminal justice systems.[27]

Despite these flaws, the global race and sense of urgency to acquire a higher level of AI has drawn large investments to the technology without paying much attention to ethical or moral considerations.[28] As a result, much of the effort aimed at fixing AI's challenges is postponed until outcomes can be measured. Similarly, most ethical guidelines are vague, lack practicality and have no enforcement mechanisms in place.[29]

However, acknowledging and identifying deficiencies in AI and rectifying these errors in the design process could offer an invaluable opportunity to address these flaws. As a result, re-imagining AI design through process philosophy will need to start by unpacking AI drawbacks, not only on a social level but also by investigating the technical aspects of AI to understand what components lead to flawed outcomes.

This type of critical perspective helps to highlight important principles that should be reconsidered in AI design by using process philosophy, outlined in the following chapters. But before stepping into discussing the challenges of AI, I am going to take a step back to unpack some of the related historical and technological aspects of AI. This gives context to the nature of "intelligence" in AI and establishes the role of data and machine learning in its manner of functioning.

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[27] Virginia Eubanks, *Automating Inequality: How High-Tech Tools Profile, Police, and Punish the Poor*, First Edition (St. Martin's Press, 2017).

[28] Luca Bertuzzi, "The Latest Dimension of the Global Race for an AI Governance Framework," The International Association of Privacy Professionals, *IAPP*, 2023, https://iapp.org/news/a/the-latest-dimension-of-the-global-race-for-an-ai-governance-framework/.

[29] Guilherme Palumbo et al., "Objective Metrics for Ethical AI: A Systematic Literature Review," *International Journal of Data Science and Analytics*, ahead of print, April 13, 2024, https://doi.org/10.1007/s41060-024-00541-w; "In the Realm of Paper Tigers – Exploring the Failings of AI Ethics Guidelines," AlgorithmWatch, 2020, https://algorithmwatch.org/en/ai-ethics-guidelines-inventory-upgrade-2020/.

Intelligent Machines: A Brief History

At the turn of the 17th century, the German mathematician and philosopher Gottfried Wilhelm Leibniz created a mechanical calculator for basic arithmetic functions and saw its potential to solve algebraic expressions and perform logical functions. [30] He described his machine as "the great instrument of reason, which will carry the forces of the mind further than the microscope has carried those of sight."[31] Leibniz thought a universal language of symbols could express all facts through calculations.[32] Moreover, he envisioned a system that translated all truth into logical steps and predicted that we could use symbols to automate human thinking.[33]

In the early 20th century, mathematician and logician Kurt Gödel challenged the possibility of the computation of all truths. His 1931 "Incompleteness theorem" proved that a logical system, a formal system, cannot explain everything since there are always true conditions that cannot be proven.[34] In *Gödel, Escher, Bach: An Eternal Golden Braid*, Douglas Hofstadter uses the analogy of a record player to explain this: "For any record player, there are records which it cannot play because they will cause its indirect self-destruction."[35] In a sense, Gödel

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[30] Oscar Schwartz, "In the 17th Century, Leibniz Dreamed of a Machine That Could Calculate Ideas - IEEE Spectrum," 2019, https://spectrum.ieee.org/in-the-17th-century-leibniz-dreamed-of-a-machine-that-could-calculate-ideas; Martin Davis, *The Universal Computer: The Road from Leibniz to Turing* (CRC Press/Taylor & Francis Group, 2018), 4.

[31] Nicholas Jolley, ed., *The Cambridge Companion to Leibniz* (Cambridge University Press, 1995), 231.

[32] Robin Robertson, *Jungian Archetypes: Jung, Gödel, and the History of Archetypes*, ebook reprint (Open Road Integrated Media, Incorporated, 2016, 2016), 56.

[33] Schwartz, "In the 17th Century, Leibniz Dreamed of a Machine That Could Calculate Ideas - IEEE Spectrum."

[34] IAS, "Kurt Gödel: Life, Work, and Legacy | Institute for Advanced Study," 2009, https://www.ias.edu/kurt-g%C3%B6del-life-work-and-legacy.

[35] Douglas R. Hofstadter, *Gödel, Escher, Bach: An Eternal Golden Braid*, 20th anniversary ed (Basic Books, 1999), 91.

showed the limits of computability by proving mathematically that not everything can be explained by logic or a sequence of rules.[36]

Later in 1936, Alan Turing also tested the limitations of computational knowledge. In *On Computable Numbers, with an Application to the Entscheidungsproblem*, published in the London Mathematical Society journal, he concluded that there are 'undecidable' problems which can't be proven true or false.[37] In a sense, Turing and Gödel underlined the limits of the knowledge that could be obtained through computation.

A Modern Inception

In February 1955, John McCarthy, a young mathematics professor at Dartmouth College in Hanover, New Hampshire, approached the Rockefeller Foundation to fund a summer seminar. In his proposal, McCarthy coined the term "artificial intelligence" to refer to what was considered a visionary project.[38] McCarthy writes that "every aspect of learning or any other feature of intelligence can, in principle, be so precisely described that a machine can be made to simulate it."[39]

In the summer of 1956, John McCarthy's proposed conference took place in the Dartmouth Math Building. The ideas and key figures from the event played a pivotal role in shaping the future development of modern Artificial Intelligence (AI). The conference was

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[36] Douglas R. Hofstadter, "Analogies and Metaphors to Explain Godel's Theorem," *The Two-Year College Mathematics Journal* 13, no. 2 (1982): 98–114, https://doi.org/10.2307/3026485.

[37] Andrew Hodges, *Alan Turing: The Enigma* (Vintage Books, 2014), xvii.

[38] Eliza Strickland, "The Turbulent Past and Uncertain Future of Artificial Intelligence - IEEE Spectrum," IEEE Spectrum, 2021, https://spectrum.ieee.org/history-of-ai.

[39] John McCarthy et al., "A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence, August 31, 1955.," *AI Magazine* 27 (2006): 12–14.

mainly focused on designing machines that could mimic human reasoning and behaviour.[40] The works presented at the conference and McCarthy's vision of an intelligent system that behaved like a human laid the groundwork for a new discipline in AI research.[41]

The conference also led to collaborative efforts between behavioural psychologists and computer scientists to study humans through their behaviour. This allowed them to ignore the inner complexities of the human mind and equate the human thinking process with the outcome of their actions. This approach, also known as symbolic AI, aimed to mimic human thinking patterns and was about tracing reasoning in humans to solve similar problems. In essence, it reduced human intelligence to rational logic.[42]

In 1957, Frank Rosenblatt introduced the perceptron algorithm that was able to learn from input data. His model proved superior in pattern recognition problems, making it one of the first practical applications of AI.[43] During the 1980s, Geoffrey Hinton and Yann LeCun expanded the idea of artificial neural nets and designed deep neural networks with interconnected nodes or neurons organized in layers. By adjusting the weights and biases of the connections between neurons, neural networks could learn better from data, which made neural networks the most effective in image and speech recognition, natural language processing, and pattern recognition tasks. In this approach, layers of neurons compute an output from given data,

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[40] Stuart J. Russell and Peter Norvig, *Artificial Intelligence: A Modern Approach*, 3rd ed, Prentice Hall Series in Artificial Intelligence (Prentice Hall, 2010), 3.

[41] Strickland, "The Turbulent Past and Uncertain Future of Artificial Intelligence - IEEE Spectrum"; J. McCarthy et al., "Old- A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence," Semantic Scholar, 1955, https://www.semanticscholar.org/paper/A-Proposal-for-the-Dartmouth-Summer-Research-on-31%2C-McCarthy-Minsky/38e61d9a65aa483ad0fb4a219fe54d4e6a2f6c36.

[42] Grace Solomonoff, "The Meeting of the Minds That Launched AI - IEEE Spectrum," 2023, https://spectrum.ieee.org/dartmouth-ai-workshop; Russell and Norvig, *Artificial Intelligence*, 3; Luca M. Possati, *Unconscious Networks: Philosophy, Psychoanalysis, and Artificial Intelligence*, Routledge Studies in Contemporary Philosophy (Routledge, 2023).

[43] David E. Rumelhart et al., *Learning Internal Representations by Error Propagation* (Institute for Cognitive Science, University of California, San Diego LA, 1985), https://apps.dtic.mil/sti/citations/ADA164453.

and by correcting for errors, enable a network to learn autonomously.[44] This shift moved the focus of AI development from logic to data. I use this contemporary approach to AI to study PAI principles.

Furthermore, the success of AI based on data highlights how the quality and quantity of input data can influence computational abilities and outcomes.[45] In other words, the importance of data lies in its role in translating the reality of human life to something that an AI system can understand. On one level, the gap between data and the reality of life determines the accuracy of AI decision-making. Additionally, the AI algorithms involved in analyzing information influence the accuracy of AI operations. To better understand how data and AI algorithms impact and change real-world scenarios into decisions, I briefly explore the elements of AI.

Key Elements in AI

AI is the publicly accepted terminology for a wide range of intelligent machines, from self-driving cars to automated customer service systems. In *Artificial Intelligence: A Modern Approach*, artificial intelligence is defined as a mathematical and engineering system that can "think rationally" and "act rationally."[46] This dissertation focuses on the subset of AI applications that leverage data-driven machine learning to "identify patterns in data and make

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[44] Yann LeCun et al., "Deep Learning," *Nature* 521, no. 7553 (2015): 436–44, https://doi.org/10.1038/nature14539; Erkam Guresen and Gulgun Kayakutlu, "Definition of Artificial Neural Networks with Comparison to Other Networks," *Procedia Computer Science*, World Conference on Information Technology, vol. 3 (January 2011): 426–33, https://doi.org/10.1016/j.procs.2010.12.071.

[45] Possati, *Unconscious Networks*, 16.

[46] Russell and Norvig, *Artificial Intelligence*, 5.

predictions accordingly."[47] Based on this definition, I explore two key elements of AI: data and machine learning.

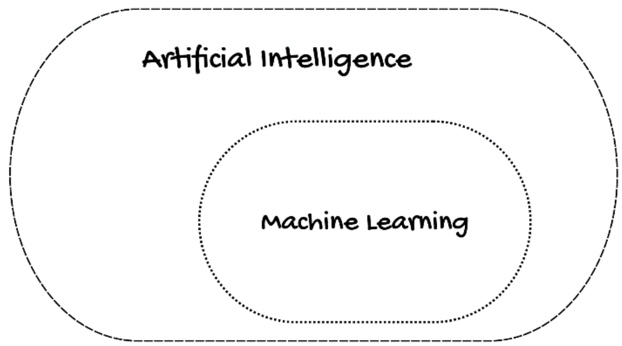

Figure 1. AI and Machine Learning

Data

Data is essential in any AI system to identify patterns and make predictions. Creating an AI system often requires big data. Big data refers to the high volume, velocity and variety of information used in analysis.[48] Data used in AI is structured into tables and spreadsheets or appears unstructured, such as a collection of images, texts, or videos and represents a set of digital information about a person, place or event.[49] Through this process, data collection transforms physical locations, people, happenings, social events, and cultural meaning into a set of numbers, text or snapshots and removes all context, feelings, meanings and nuances from them.

[47] Kelly Joyce et al., "Toward a Sociology of Artificial Intelligence: A Call for Research on Inequalities and Structural Change," *Socius: Sociological Research for a Dynamic World* 7 (January 2021): 237802312199958, https://doi.org/10.1177/2378023121999581.

[48] Andrea De Mauro et al., "A Formal Definition of Big Data Based on Its Essential Features," *Library Review* 65, no. 3 (2016): 122–35, world, https://doi.org/10.1108/LR-06-2015-0061.

[49] Mark Jeiran et al., "Common Data Format," *Automatic Target Recognition XXXII* 12096 (May 2022): 62–76, https://doi.org/10.1117/12.2618565.

For example, for humans, a home address is associated with people, culture, emotions, memories, the history of the land, the surrounding landscape and much more. However, as a record in a dataset, a home address is a set of characters. Since AI relies on input data to reach its outcome, the abstraction and reduction in the data collection process directly impact AI's ability in decision-making. Although the abstraction from the idea of a "home" to a string of letters makes AI fast at computation, it leaves out the context, due to its design.[50] This is how data and, thus, AI, by design, remove context. Consequently, re-imagining AI design through a process framework should consider this flaw and provide measures to re-incorporate the context.

Beyond the collection process, data needs to go through various stages of processing to be prepared for analysis by AI. First, data is cleaned by removing unwanted records and by filling in or removing missing values, which could involve transforming data into a more usable format for analysis.[51] Furthermore, data is divided into sets for training, testing and validation in machine learning. To make data effective in computing, various processing steps strip the details, enforce arbitrary rules and render the information more reductive. Data collection and data processing play important roles in making AI functional, yet they remove context by design. Consequently, re-considering AI design requires rethinking the nature of data collection and data processing in decision-making.

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[50] Peter J. Denning and John Arquilla, *The Context Problem in Artificial Intelligence – Communications of the ACM*, December 1, 2022, https://cacm.acm.org/opinion/the-context-problem-in-artificial-intelligence/.

[51] Solveig Badillo et al., "An Introduction to Machine Learning," *Clinical Pharmacology & Therapeutics* 107, no. 4 (2020): 871–85, https://doi.org/10.1002/cpt.1796.

Machine Learning

Machine Learning (ML) is a set of algorithms that find patterns in data. An ML process can be supervised or unsupervised. In supervised machine learning, AI learns by consuming data that is labelled clearly. In unsupervised machine learning, the system identifies patterns on its own. ML algorithms use training data to find a pattern or model which they can use to evaluate new data. Hence, designing an AI system involves finding and fine-tuning the right ML model. A machine learning algorithm could be made by using existing models or coded from scratch. The choice of ML algorithms often depends on the data and project needs. For example, in processing images, text, or audio, each requires different algorithms.

ML algorithms are designed to learn from data and make predictions. However, finding the right ML model is a selective process that involves multiple iterations, where the developers fine-tune the machine learning algorithm or alter the data formats to find the right model. An ML model that fits best produces the least error rate with the validation data. Once trained, this ML model can make future predictions based on new data. The ML process aims to provide the highest prediction accuracy with the least number of false positives and false negatives. However, the steps and decisions involved in settling on the right ML model with an acceptable error rate mean that ML is always biased and dependent on the development process.[52]

[52] Russell and Norvig, *Artificial Intelligence*, 651–53; Sara Brown, "Machine Learning, Explained | MIT Sloan," April 21, 2021, https://mitsloan.mit.edu/ideas-made-to-matter/machine-learning-explained; "Machine Learning - an Overview | ScienceDirect Topics," accessed April 22, 2022, https://www.sciencedirect.com/topics/psychology/machine-learning; "What Is Machine Learning? - An Informed Definition," Emerj Artificial Intelligence Research, accessed May 9, 2025, https://emerj.com/what-is-machine-learning/; "What Is Machine Learning (ML)? | IBM," September 22, 2021, https://www.ibm.com/think/topics/machine-learning.

Likewise, ML algorithms are built on mathematical foundations and are a "cousin" to statistical methods.[53] This process requires feature selection by which hundreds of variables are reduced to a limited number of possibilities. This reduction improves prediction performance and pattern recognition.[54] However, at the same time, it trims down a complex set of interconnected variables into a few selected features. Thus, the feature selection process often removes important variables and introduces biases into the ML process.

Overall, the selection process to find the right ML and the feature selection at the core of ML algorithms are inherently biased and can significantly impact AI outcomes. Consequently, re-imagining AI design through a process framework should consider the inherent bias built into designing and building ML models and provide possibilities for mitigating it.

In this dissertation, I am seeking to construct a framework that makes AI aware of the larger context and provides a set of protocols to mitigate these biases and abstractions. Before approaching process philosophy to unpack these elements, I examine AI challenges through a social lens. This helps to narrow down the important factors that should be included in rethinking AI design through the process framework.

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[53] Samuel G. Finlayson et al., "Machine Learning and Statistics in Clinical Research Articles—Moving Past the False Dichotomy," *JAMA Pediatrics* 177, no. 5 (2023): 448–50, https://doi.org/10.1001/jamapediatrics.2023.0034; Michele Bennett et al., "Similarities and Differences between Machine Learning and Traditional Advanced Statistical Modeling in Healthcare Analytics," arXiv:2201.02469, preprint, arXiv, January 7, 2022, https://doi.org/10.48550/arXiv.2201.02469.

[54] Silvia Cateni et al., "Variable Selection and Feature Extraction Through Artificial Intelligence Techniques," in *Multivariate Analysis in Management, Engineering and the Sciences* (IntechOpen, 2013), https://doi.org/10.5772/53862; Girish Chandrashekar and Ferat Sahin, "A Survey on Feature Selection Methods," *Computers & Electrical Engineering*, 40th-year commemorative issue, vol. 40, no. 1 (2014): 16–28, https://doi.org/10.1016/j.compeleceng.2013.11.024.

Critical Approaches to AI

Shortsighted Development

The first problem with AI is its techno-centric obsession. Most development is guided by the increasingly rapid growth of technology. This means that solving technological challenges is prioritized over resolving AI's ethical issues or its lack of common sense. In addition, much AI development is reflective of the experts behind it.

According to the *AI Index Report,* released annually by Stanford HAI, the AI field is predominantly white and male. Despite some positive trends in the 2024 report, this imbalance in the field is strongly persistent.[55] This means that most AI systems are created from the perspective of their development teams, which limits AI in its perception. A clear example of this biased development can be spotted in Facial Recognition Technology (FRT). The homogeneity of AI developers means that FRT is often criticized for not being able to identify darker-skinned females, gender minorities, and marginalized ethnicities, who are frequently misclassified by the system.[56]

Bias in Data

People often assume that data is objective information. Rick Smolan, co-author of *The Human Face of Big Data,* argues that data is neutral but can be used for good or evil.[57] Catherine

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[55] *Artificial Intelligence Index Report 2021* (Stanford Institute for Human-Centered Artificial Intelligence (HAI), n.d.), https://aiindex.stanford.edu/report/; *Artificial Intelligence Index Report 2024.* (Stanford Institute for Human-Centered Artificial Intelligence (HAI), 2024), https://aiindex.stanford.edu/report/.

[56] S. Yucer et al., "Racial Bias within Face Recognition: A Survey," *ACM Computing Surveys* 57, no. 4 (2024), https://doi.org/10.1145/3705295; Joy Buolamwini, "Gender Shades: Intersectional Accuracy Disparities in Commercial Gender Classification," MIT Media Lab, 2018, https://www.media.mit.edu/publications/gender-shades-intersectional-accuracy-disparities-in-commercial-gender-classification/.

[57] Daniel Honan, "Big Data Is Neutral: A Tool for Both Good and Evil - Big Think," 2013, https://bigthink.com/articles/big-data-is-neutral-a-tool-for-both-good-and-evil/.

D'Ignazio and Lauren Klein, in *Data Feminism,* are critical of data collection and point to the corporate interest in determining the focus of data creation efforts.[58] Likewise, Rob Kitchin, in *Data Revolution,* reasons that "data is always framed." As a result, it should be considered within the wider network that influences data, which he calls "assemblages."[59] Therefore, looking critically at data means investigating how it is affected by cultural, political, economic, and technological factors, and it is always tangled in its context.[60] This perception of data requires scrutinizing the institutions behind data collection and asking questions about what is left out of the process. Equally, it translates to inquiries into data analysis, and what questions are asked about it. Overall, when it comes to re-imagining AI design, a noteworthy conclusion is that data should be considered beyond its quantitative or qualitative value.

Data and power dynamics

AI systems are heavily influenced by the data they consume. As a result, those who collect or manipulate the data exert more influence on the power dynamics of AI decision-making. Equally, if a bias exists in the raw data, the AI system will replicate it in its decision-making.[61] Sabrina Leonelli voices concerns about big data quality and its role in enabling

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[58] Lauren Klein and Catherine D'Ignazio, "Data Feminism for AI," *2024 ACM Conference on Fairness, Accountability, and Transparency*, ACM, June 3, 2024, 100–112, https://doi.org/10.1145/3630106.3658543.

[59] Rob Kitchin, *The Data Revolution: Big Data, Open Data, Data Infrastructures & Their Consequences* (SAGE Publications, 2014), 29; Kitchin, *The Data Revolution*, 176.

[60] Kitchin, *The Data Revolution*, 29; Kitchin, *The Data Revolution*, 176.

[61] Zhisheng Chen, "Ethics and Discrimination in Artificial Intelligence-Enabled Recruitment Practices," *Humanities and Social Sciences Communications* 10, no. 1 (2023): 1, https://doi.org/10.1057/s41599-023-02079-x.

unbalanced power structures.[62] In other words, bias in input data influences AI decision-making. This is known as “predictive bias” and occurs when the data source is unbalanced.[63]

A straightforward account of predictive bias is well documented in what happened to Robert Williams from Farmington Hills, Michigan. Williams, a family man, was handcuffed and arrested in front of his house by Detroit police for stealing watches from a Shinola retail store. He spent 30 hours in jail until the police realized that the facial recognition software had falsely flagged him in the robbery.[64] AI-powered crime detection claims to improve public safety by detecting crimes early and helping officials address the crimes quickly.[65] However, such AI systems are trained on police records and prison populations that are historically overrepresented by marginalized ethnic communities.[66] As a result, these systems are more likely to flag such minorities and perpetuate the existing injustice.[67]

The systemic discrimination of AI tools against marginalized groups is not limited to the criminal system. For instance, a 2024 report by Amnesty International raises concerns about how

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62 S Leonelli, “What Difference Does Quantity Make? On the Epistemology of Big Data in Biology,” *Big Data & Society* 1, no. 1 (2014): 205395171453439, https://doi.org/10.1177/2053951714534395.

63 Manish Raghavan et al., “Mitigating Bias in Algorithmic Hiring: Evaluating Claims and Practices,” SSRN Scholarly Paper no. 3408010, Rochester, NY, June 21, 2019, https://doi.org/10.2139/ssrn.3408010; Chen, “Ethics and Discrimination in Artificial Intelligence-Enabled Recruitment Practices.”

64 Bobby Allyn, “Facial Recognition Leads to False Arrest of Black Man in Detroit,” News, NPR, 2020, https://www.npr.org/2020/06/24/882683463/the-computer-got-it-wrong-how-facial-recognition-led-to-a-false-arrest-in-michig; Kashmir Hill, “Wrongfully Accused by an Algorithm,” The Seattle Times, June 24, 2020, https://www.seattletimes.com/business/technology/wrongfully-accused-by-an-algorithm/.

65 Rithya Pisati et al., “A Profound Review of AI-Driven Crime Detection in CCTV Videos,” *2024 Sixth International Conference on Computational Intelligence and Communication Technologies (CCICT)*, April 2024, 193–99, https://doi.org/10.1109/CCICT62777.2024.00040.

66 Md Aminur Rab Ratul, “A Comparative Study on Crime in Denver City Based on Machine Learning and Data Mining,” arXiv:2001.02802, preprint, arXiv, January 9, 2020, https://doi.org/10.48550/arXiv.2001.02802.

67 Kade Crockford, “How Is Face Recognition Surveillance Technology Racist? | ACLU,” *American Civil Liberties Union*, June 16, 2020, https://www.aclu.org/news/privacy-technology/how-is-face-recognition-surveillance-technology-racist; Thaddeus L. Johnson and Johnson, Natasha N., “Police Facial Recognition Technology Can’t Tell Black People Apart,” Scientific American, 2023, https://www.scientificamerican.com/article/police-facial-recognition-technology-cant-tell-black-people-apart/.

Denmark's automated welfare system targets people with disabilities, low-income individuals, migrants, refugees, and marginalized racial groups for fraud.[68] A more common example might be AI-powered employee recruitment, especially as it becomes more popular.[69] Despite the goal of expediting the hiring process, these systems lead to "discriminatory hiring practices based on gender, race, colour, and personality traits."[70] For instance, in the *Atlas of AI*, Crawford brings attention to a case in Amazon's hiring where female candidates with equal qualifications to men were excluded from the hiring process.[71]

Without critical attention, AI seems to double down on existing power dynamics and accentuate existing inequalities. In *Race After Technology,* Ruha Benjamin questions the role of AI in entrenching the status quo. Benjamin writes that "with emerging technical tools, we might assume that racial bias will be more scientifically rooted out. Yet rather than challenging or overcoming the cycles of inequity, technical fixes too often reinforce and even deepen the status quo."[72]

Ultimately, the problem with raw data in an AI learning process is "not just a technical one" but a "cultural construct."[73] Existing power structures, historical inequalities, data quality,

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[68] Amnesty International, *Denmark: Coded Injustice: Surveillance and Discrimination in Denmark's Automated Welfare State* (2024), https://www.amnesty.org/en/documents/eur18/8709/2024/en/; Amnesty International, "Denmark: AI-Powered Welfare System Fuels Mass Surveillance and Risks Discriminating against Marginalized Groups – Report," Amnesty International, November 12, 2024, https://www.amnesty.org/en/latest/news/2024/11/denmark-ai-powered-welfare-system-fuels-mass-surveillance-and-risks-discriminating-against-marginalized-groups-report/.

[69] J. Stewart Black and Patrick van Esch, "AI-Enabled Recruiting: What Is It and How Should a Manager Use It?," *Business Horizons*, ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING, vol. 63, no. 2 (2020): 215–26, https://doi.org/10.1016/j.bushor.2019.12.001.

[70] Chen, "Ethics and Discrimination in Artificial Intelligence-Enabled Recruitment Practices."

[71] Kate Crawford, *Atlas of AI: Power, Politics, and the Planetary Costs of Artificial Intelligence* (Yale University Press, 2021), 130.

[72] Benjamin, *Race after Technology*, 13.

[73] Matteo Pasquinelli and Vladan Joler, "The Nooscope Manifested: AI as Instrument of Knowledge Extractivism," *AI & SOCIETY* 36, no. 4 (2021): 1263–80, https://doi.org/10.1007/s00146-020-01097-6.

classification, keyword definition, and data reliability all play a role in the outcomes and should be accounted for in every stage of a machine-learning process.[74] One of the important factors in reimagining AI design is taking into account its position and integration into society, not as a tool that helps in automation but as a player who, through its role, has a major influence on various social dynamics. As I discuss later in this chapter, Whitehead's philosophy is built on a unified system of reality. Thus, this aspect of process thinking allows for re-envisioning AI as part of a unified system.

Simplified Intelligence

Another problematic aspect of AI is the vague nature of its intelligence. In AI development, there is no common set of milestones or well-defined measurements that allow researchers to "agree that genuine progress is being made."[75] In its place, there appears to be a consensus that we recognize intelligence when we build it. As a result, instead of clear benchmarks, the goal of AI development has become to mimic human abilities.[76]

When John McCarthy coined the term artificial intelligence, he assumed that "intelligence is the computational part of the ability to achieve goals in the world."[77] This gave rise to "computational psychology" and collaboration among computer science, psychology, and cognitive scientists to replicate human behaviour through mathematical modelling.[78] From its

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[74] Leonelli, "What Difference Does Quantity Make?"

[75] Christopher Summerfield, *Natural General Intelligence: How Understanding the Brain Can Help Us Build AI* (Oxford University Press, 2023), 34.

[76] Summerfield, *Natural General Intelligence*, 34.

[77] Dagmar Monett et al., "John McCarthy's Definition of Intelligence," *Journal of Artificial General Intelligence* 11, no. 2 (2020): 1–100, https://doi.org/10.2478/jagi-2020-0003.

[78] Agre, "Toward a Critical Technical Practice: Lessons Learned in Trying to Reform AI," 20.

inception, the goal of artificial intelligence technology has been to mimic human abilities in decision-making and behaviour. But does this mean that AI can be intelligent?

Dan McQuillan argues that AI can never be intelligent. He writes that "there is no intelligence in artificial intelligence."[79] Instead, McQuillan sees machine learning intelligence as nothing more than a "mathematical minimization," referencing how AI concludes a process of error reduction, during which it decreases the difference between the prediction and the actual values. Using this process, a minimal loss function in training means that AI is essentially a system for numerical pattern recognition, closely enmeshed with the data used in its training. A direct consequence of this perspective is that the knowledge gained through AI and machine learning cannot be generalized or considered universal.[80]

Intelligence and Adaptation

A pragmatic approach to defining intelligence can be found in its purpose. In psychology, human intelligence is defined as the difference in cognitive performance that creates an advantage by increasing adaptation to the environment.[81] Seeing intelligence as an adaptability mechanism breaks intelligence into a holistic set of abilities that work together to increase the chances of survival in a changing world. Consequently, human intelligence is not confined to producing and processing knowledge. According to this definition of intelligence, physical strength, emotional sensitivity, social charisma, and many other abilities that contribute to human

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[79] Dan McQuillan, "People's Councils for Ethical Machine Learning," *Social Media + Society* (Thousand Oaks, United Kingdom) 4, no. 2 (2018), http://dx.doi.org/10.1177/2056305118768303.

[80] Pasquinelli and Joler, "The Nooscope Manifested"; McQuillan, "People's Councils for Ethical Machine Learning."

[81] Joachim Funke, "Intelligence: The Psychological View," in *Intelligence - Theories and Applications*, ed. Rainer M. Holm-Hadulla et al. (Springer International Publishing, 2022), https://doi.org/10.1007/978-3-031-04198-3_7.

adaptability are counted as intelligence. Such adaptability requires sensitivity and a connection to the environment. Equally, it means having the ability to scan the environment for adequate feedback and adjust course accordingly. It means taking into consideration context and being able to make decisions in novel situations. This feedback and continuous learning loop are one of the key missing elements in the current AI design. This is where Whitehead's process approach to reality, through adaptability and transformation, can guide re-imagining AI design.

Lucy Suchman, an anthropologist in human-computer interaction, argues that machine intelligence lacks situational knowledge. Situatedness refers to the insights gained from the specific contexts, experiences, or environments in which someone is located. She observes that when it comes to AI, the idea of "humanness" is taken for granted, "even though the humanness assumed in discussions of the potential success (or the inevitable failure) of attempts to replicate the human mechanically is typically stripped of its contingency, locatedness, historicity, and specific embodiments."[82] The entanglement of intelligence with the body, location, and personal experience is a question of perception and what it means to interact and behave as a human.

Maurice Merleau-Ponty makes a similar argument about knowledge, intelligence, and human experience. This French philosopher of the early 20th century saw human experience and perception as entangled with the body's physicality and the way it interacts with the environment. In *Phenomenology of Perception*, he writes that "the body is our general medium for having a world" and experiencing it.[83] If human perception and cognition are deeply connected to the body's interaction with its environment, then it follows that intelligence in AI

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[82] Lucille Alice Suchman, *Human-Machine Reconfigurations: Plans and Situated Actions*, 2nd ed (Cambridge University Press, 2007), 245.

[83] Maurice Merleau-Ponty, *Phenomenology of Perception: An Introduction*, Reprint, trans. Colin Smith, Routledge Classics (Routledge, 2006), 146.

does not cover all aspects of human knowledge, since facets such as situation, moral, and ethical reasoning, intuition, common sense, subjective experience, and embodied awareness are not computable. Where does that take us in comparing machine intelligence to humans in the race to create machines that are equally or even more intelligent than humans?

Hubert Dreyfus, an American philosopher and AI critic, draws on Merleau-Ponty's philosophy to challenge the abstract nature and limited scope of intelligence in AI. He proposes a "model of skill acquisition" to measure and compare human skill acquisition to AI. In Dreyfus's model, reaching the ultimate *Expert* level requires holistic cognition and skills that can adapt to novel and complex situations and go beyond rules and patterns. Similarly, this type of intelligence requires "a nonformal form of information processing which is possible only for embodied beings —where being embodied does not merely mean being able to move and to operate manipulators."[84] In other words, Dreyfus doesn't see AI reaching an expert level, no matter how much improvement we achieve.

Despite such criticism, AI has the potential to help humans solve many of their problems. However, how AI is framed makes it problematic. Many of the challenges I have explored in AI stem from framing AI as an autonomous, intelligent machine that is capable of surpassing human capacities. At its core, AI development follows a clear ideological path: the belief that humans are essentially mechanical systems made of organic matter, that can be replicated or even enhanced through computational efficiency. In reality, we lack a complete understanding of the facets of the human mind, such as intuition and consciousness. Given this, how can we realistically expect to replicate the "human machine"?

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[84] Hubert L. Dreyfus, "Artificial Intelligence," *The ANNALS of the American Academy of Political and Social Science* 412, no. 1 (1974): 21–33, https://doi.org/10.1177/000271627441200104.

What if we can look at AI for what it is, a "fast information processing machine?" Accepting AI's inability to match human-type intelligence allows us to expand its potential through different means. This vision requires a different way of looking at the role of the technology as a collaborator rather than as an autonomous machine.

Through PAI principles, I propose an alternative AI design to overcome its typical biases and limitations. The key shortcoming of AI is its inability to replicate the "hidden knowledge" that humans gain through lived experience, consciousness, social connections, the physical body, and intuitive thinking. From a pragmatic perspective, the first step in addressing the gap between AI and human capabilities is providing the missing parts. This means creating a clear structure to facilitate collaboration between the machine and human agents, to include what could not be reached through "computational intelligence" in the machines. This dissertation is built on this premise and works through the lens of process philosophy to create a set of protocols for working with AI and guiding its design to include its missing components and make AI systems that are more context-aware and adaptable. To reach this perspective, we must first take a closer look at the inner workings of Whitehead's process philosophy.

Whitehead's Philosophy as a Framework for Rethinking AI

The project to use AI meaningfully, in a way that accounts for context, bias, and abstraction, requires a framework to rethink AI. This framework needs to consider the holistic nature of reality, account for adaptability in intelligence design, and provide a perspective for adjustment to the environment. For this, I turn to Whitehead, because the process model of reality offers a theoretical framework for understanding the empirical system through change, and adaptability and offers a unified model for understanding reality.

A Mathematical philosopher

Alfred North Whitehead's philosophical writings followed a lifetime of being immersed in natural sciences. Through his metaphysical works, Whitehead unpacks the nature of reality through biology, physics, and mathematics. To do this, he applies his ideas from mathematics and physics and offers a model of reality that could be described as an interconnected web of living organisms, forever changing, evolving and becoming.[85]

Coming from a family of Anglican clergymen, young Alfred Whitehead went to Cambridge on a scholarship to study mathematics in 1880. While at Cambridge, he became interested in Michael Faraday and James Clerk Maxwell's electromagnetic field theory. Following this interest, he took lectures with Maxwell's accomplished pupil and editor W.D. Niven, which led to his dissertation on Maxwell's work, *A Treatise on Electricity and Magnetism*, under his guidance.[86] Maxwell was a Scottish mathematician who turned Faraday's discoveries in electromagnetism into mathematical models. Maxwell and Faraday's work shows that space is filled with "lines of force" that connect all matter, making it possible for electric and magnetic interactions to happen over distances.[87] Whitehead's engagement with the work of Faraday and Maxwell deeply influenced his ideas on interconnectedness and the changing nature of the universe.[88] Moreover, his interest in electromagnetic and general relativity led him to

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[85] *What Is Process Thought? - Lesson 2*, directed by Jay McDaniel, 2012, 6:16, https://www.youtube.com/watch?v=V0O_vx7rn6U; Thomas E. Hosinski, *Stubborn Fact and Creative Advance: An Introduction to the Metaphysics of Alfred North Whitehead* (Rowman & Littlefield, 1993), 27.

[86] Victor Lowe, *Understanding Whitehead*, 2nd ed. (Johns Hopkins Press, 1966), 5–6; Rémy Lestienne, *Alfred North Whitehead, Philosopher of Time* (World Scientific, 2022), 1–3; Lawrence Fagg, "Electromagnetism, Time and Immanence in Whitehead's Metaphysics," *Process Studies* 26, no. 3/4 (1997): 308–17, https://doi.org/10.5840/process1997263/44.

[87] James O'Connell, "Faraday, Maxwell, and Lines of Force," *Journal of the Washington Academy of Sciences* 93, no. 2 (2007): 1–6.

[88] Leemon B. McHenry, *The Event Universe: The Revisionary Metaphysics of Alfred North Whitehead*, Crosscurrents (Edinburgh University Press, 2015), 43.

develop a metaphysical framework based on the interconnectedness of all entities, where interactions, transformation, and creativity run the universe.[89]

Whitehead's cosmology parallels the process of 'decoherence'[90] in quantum mechanics with how the potentials of actual entities are actualized through interaction.[91] Similarly, instead of accepting the world as a set of static objects, his ontology describes a universe where the world is made of processes that continuously interact, change, and integrate experiences to evolve.

The earliest accounts of Whitehead's transition from his mathematical physics to his philosophical interpretation of relativity are offered in his Tanner Lectures, later published as *The Concept of Nature*.[92] This comes with a companion reader that includes the mathematical work behind his idea, titled *An Enquiry Concerning the Principles of Natural Knowledge*.[93] Whitehead's most comprehensive work, *Process and Reality*, encapsulates much of these early writings and expands to cover more complex cosmological questions like the role of the Divine and the overarching creative process. Overall, Whitehead's philosophy aims to offer a coherent

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[89] Alfred North Whitehead, *The Concept of Nature: The Tarner Lectures Delivered in Trinity College, November 1919*, Cambridge philosophy classics edition, Cambridge Philosophy Classics (Cambridge University Press, 1920), vi–viii; Alfred North Whitehead, *An Enquiry Concerning the Principles of Natural Knowledge*, 2nd ed. (University Press, United Kingdom, 1919), 7, GUTENBERG EBOOK.

[90] In quantum physics, decoherence happens in three stages: First, a particle is in a superposition of states, meaning it has no fixed position and can simultaneously exist in multiple possibilities. Second, the particle interacts and becomes entangled with its environment. These interactions influence the particle's potential outcomes and cause the superposition to break down. In the third stage, the particle collapses into a definite state, loses its coherence due to the environmental interaction, and becomes part of the classical, observable world by settling into a specific position.

[91] Michael Epperson, "The Correlation of Quantum Mechanics and Whitehead's Philosophy," in *Quantum Mechanics and the Philosophy of Alfred North Whitehead* (Fordham University Press, 2004), 120–21, https://doi.org/10.2307/j.ctvh4zh83.8; Arthur Holmes, "A History of Philosophy | 61 Whitehead's Process Philosophy," August 11, 2015, https://www.youtube.com/watch?v=ysTx1c5-A7s; Guido Bacciagaluppi, "The Role of Decoherence in Quantum Mechanics," in *The Stanford Encyclopedia of Philosophy*, Fall 2020, ed. Edward N. Zalta (Metaphysics Research Lab, Stanford University, 2020), https://plato.stanford.edu/archives/fall2020/entries/qm-decoherence/.

[92] Whitehead, *The Concept of Nature*, 3.

[93] Whitehead, *The Concept of Nature*, 3.

system of ideas that can interpret every aspect of our experience.[94] His ambition was to develop a comprehensive model of reality that was universal enough to explain all its entities.[95] In turn, he created an organic philosophy to understand reality through natural sciences.[96]

In this dissertation, I apply Whitehead's philosophical ideas to AI design to create a new understanding of AI technology through relationships that change over time. In understanding AI technology through Whitehead's philosophy, there are a few things worth considering. First, Whitehead's philosophy directly addresses the empirical method at the heart of AI. Second, Whitehead's philosophy offers two possibilities: one to critique the assumptions behind the empirical method, and another to speculate on possibilities and solve such problems.[97] Thus, looking at AI design through process philosophy not only offers a ground for probing the technology but can also inspire a vision of AI that could go beyond data fitting and machine learning models. Before applying process philosophy to understanding AI, I explore some of the key elements of this philosophy.

Key Concepts in Process Philosophy

The process-oriented framework is a conceptual model built underneath physical reality. You might think of process ontology as a framework describing an operating system beneath the material world. In an operating system like Windows or macOS, complex applications work on top of basic operations that interact, exchange, save data, and run commands. These working operations below the user interface make what is happening on the screen possible for the user,

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[94] Whitehead, *Process and Reality*, 3.

[95] Whitehead, *Process and Reality*, 3; Hosinski, *Stubborn Fact and Creative Advance*, 23–28.

[96] Donald W. Sherburne, *A Key to Whitehead's Process and Reality* (1966), 6.

[97] Holmes, "A History of Philosophy | 61 Whitehead's Process Philosophy."

such as typing in a text editor and browsing the Internet. In a process-oriented framework, the smallest operational units under the physical reality are called events or "the ultimate facts of nature."[98] Whitehead refers to these as the smallest units of reality that interact, exchange data, and make physical reality possible.

Events and Actual Entities

Actual entities or events are units of space-time that are spreading across the electromagnetic field.[99] Actual entities are like the idea of a "spacious present" developed by William James as a "temporal duration block."[100] For William James, a spacious present is the "fact of our immediate experience" and "a vaguely vanishing backward and forward fringe."[101] Steven Shaviro compares an actual entity to Deleuze's idea of a singularity, as "a point of inflection or of discontinuous transformation."[102] This is because a singularity and an actual occasion represent transformation and the emergence of new possibilities or novelties. They also represent dynamism and creativity through unpredictable changes rather than through a linear process.

Here, the terminology requires some clarification. In Whitehead's philosophy, events and actual entities refer to the same phenomenon. Event, a term used in earlier works, is replaced by "actual entities" and "actual occasions" in *Process and Reality*.[103] All three terms – events, actual

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[98] Whitehead, *The Concept of Nature*, 42.

[99] McHenry, *The Event Universe*, 2.

[100] Pierfrancesco Basile, *Leibniz, Whitehead and the Metaphysics of Causation* (Palgrave Macmillan, 2009), 92.

[101] William James, *The Principles of Psychology* (Henry Holt and Company, 1918), 1:660,565, Gutenberg eBook.

[102] Steven Shaviro, *Without Criteria: Kant, Whitehead, Deleuze, and Aesthetics*, First MIT Press paperback edition, Technologies of Lived Abstraction (The MIT Press, 2012), 44.

[103] In the earlier work such as *The Concept of Nature* Whitehead uses the term events to discuss the smallest units of happening. Instead, in *Process and Reality,* he refers to events as "actual occasions" or "actual entities"

occasions and actual entities – refer to the smallest units of reality. In this dissertation, I use the terms interchangeably.[104]

In *Process and Reality*, Whitehead writes that 'actual entities' and 'actual occasions' are the final real things. The world is made up of them, and there is nothing more real beneath them.[105] Although there are variations in terms of importance and function, there is nothing in the universe that exists outside of them. Thus, Whitehead places all entities on the same level of existence.[106] For example, "God is an actual entity," and so is "the most trivial puff of existence in far-off space."[107]

Process

A process explains the relationship between actual entities. Almost everything we do, observe, or think about can be interpreted through a process. For example, a seed growing into a plant is a process, and so is reading a book, a flash of a new idea, or meeting a friend. The concept of the process could be understood through its contrast with the Western philosophical tradition, "in favour of things."[108] Much of Western philosophy is concerned with things versus subjects, meaning human subjectivity comes first in understanding anything. In contrast, in the process view, the world comes first, and subjectivity comes second.[109] Process philosophers see

[104] An "occasion" is changing and exists in the process of becoming. For example, a momentary feeling is an occasion. According to Whitehead, all actual entities except "God" are occasions. Since they are changing and becoming.

[105] Whitehead, *Process and Reality*, 18.

[106] Whitehead, *Process and Reality*, 18.

[107] Whitehead, *Process and Reality*, 18.

[108] Nicholas Rescher, *Process Philosophy: A Survey of Basic Issues* (Univ. of Pittsburgh Press, 2000), 4.

[109] *Process Philosophy | Internet Encyclopedia of Philosophy*, n.d., accessed August 7, 2023, https://iep.utm.edu/processp/.

processes as "a series of events or experiential moments."[110] These events are linked and flow along other happenings, placing all and everyone permanently "in media's res," or in the middle of a story.[111] This is in opposition to the dominant mechanistic philosophy of Sir Isaac Newton, which asserts that reality is a combination of solid objects. Or the idea of substance in René Descartes's metaphysics that accounts for "mental substance" alongside the "physical substance." Process thinking replaces the idea of thingness and substance with "an appreciation for unrelenting change, self-organization, contingency, fluidity, and novelty"[112].

Books, Chairs, Trees

Whitehead does not reject physical reality. He does not think that physical reality is only an expression of the mind or "somehow mental in its inner essence."[113] He does not want to replace the objective world with ideas. Instead, the material universe is built on an operating system-like model that works with processes and actual entities to generate its structure. Whitehead writes that "an ordinary physical object, which has temporal endurance, is a society."[114] Hence, objects are societies of "actual occasions." Thus, common objects are collections of actual entities, which are named societies. Therefore, a tree, a rock, a chair, a dog, or a human body all resemble societies. Similarly, when entities or societies interact temporarily, they create a network that Whitehead calls a nexus.

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[110] Edward Branigan, "A Process Philosophy Framework for Film Theory and Aesthetics," *New Review of Film and Television Studies* 17, no. 2 (2019): 185–210, https://doi.org/10.1080/17400309.2019.1591670.

[111] Branigan, "A Process Philosophy Framework for Film Theory and Aesthetics."

[112] Charles S. Peirce and Cornelis De Waal, *Illustrations of the Logic of Science* (Open Court, 2014).

[113] T.L.S. Sprigge, "Idealism," in *Routledge Encyclopedia of Philosophy*, 1st ed. (Routledge, 2016), https://doi.org/10.4324/9780415249126-N027-1.

[114] Whitehead, *Process and Reality*, 35.

Becoming

Whitehead's vision of process reality is an evolutionary model in which all processes learn, evolve, and adapt through continuous interaction with their environment. This constant change leads to what he called 'becoming,' a state of continuous growth and transformation. Each actual entity or society, in its interaction with the world, moves toward greater complexity and novelty and is always in the process of becoming something new.

Interacting with the environment, an actual entity considers its experiences (prehension) and incorporates them into becoming something new by integrating new possibilities (concrescence). According to process ontology, becoming is about going through transformation until satisfaction is reached as "the final cause of the concrescence."[115]

In process philosophy, "creativity is the ultimate behind all forms, inexplicable by forms, and conditioned by its creatures."[116] The forces of novelty and creativity drive the ongoing process of becoming in the cosmos.

The Life of an Actual Entity

Much of Whitehead's philosophical model revolves around a model for creation and becoming. Here, we explore this model as the cycle of creation, interaction, and transformation. Process philosophy focuses on the becoming of actual entities. An actual entity begins with an initial step called "initial aim."[117] The actual entity starts life by interacting with its environment.

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[115] Whitehead, *Process and Reality*, 212.

[116] Whitehead, *Process and Reality*, 20.

[117] In this context, God is the principle of concrescence; that is, He is the actual entity from which each temporal concrescence receives its initial aim, marking the beginning of its self-causation. For further detail, see Alfred Whitehead, *Process and Reality* (New York: The Free Press), 244.

These interactions with the surroundings change the initial entity and make it transform and adapt through this engagement.

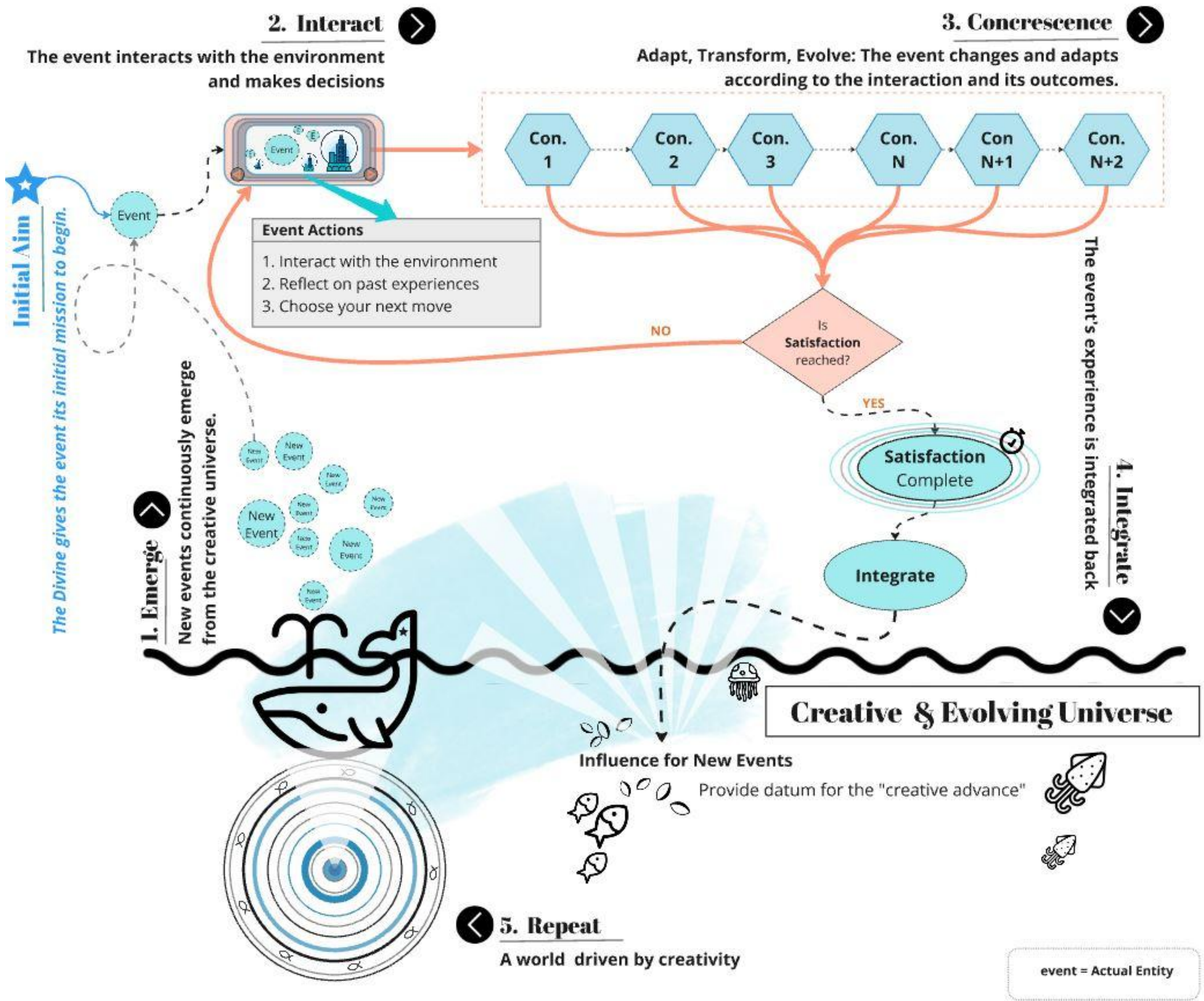

Figure 2. Cosmic Model of Reality in the Process Universe

The changes made in the entity because of these interactions are the process of concrescence. The entity adapts and integrates influences from the environment. Multiple concrescences lead the entity to a final stage or 'satisfaction' state. Once an event reaches its satisfaction, it integrates its experience into the creative universe. This cycle of becoming drives the universe and its evolutionary process and adds new possibilities to reality. The goal of process reality is creativity and novelty, so this process continues to unfold more possibilities.

Critique of Traditional Metaphysics in AI

AI technology is built on traditional metaphysics based on the Cartesian model of reality, where human subjects measure and study objects. Ultimately, AI uses empirical methods to understand the world of objects and their properties. Traditional metaphysics is concerned with understanding the nature of reality by focusing on objects, their characteristics, and their categories through the empirical method. In his critique of empirical methods, Whitehead writes that "the narrow efficiency of the scheme was the very cause of its supreme methodological success."[118] Similarly, he believes that "the more subtle employment of our senses," and "the request for meanings and the coherence of thought" will take us to the limits of empirical reasoning.[119] In other words, sense perception in humans is not only about the accuracy of observation, but rather it is about making meaning and forming connections between ideas. Although the empirical method can observe accurately, it can't step into the realm of conceptual ideas and make meaning without human assistance. As a result, empirical reasoning will always have limitations in making meaningful associations and cannot step beyond a certain level of abstraction. Thus, viewing empirical reasoning through the lens of process philosophy means integrating empirical results with the human experience to include values, meaning, and common-sense relations in the outcome.

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[118] Alfred North Whitehead, *Science and the Modern World*, A Mentor Book (New American Library, 1960), 22.

[119] Whitehead, *Science and the Modern World*, 17.

Static Object and Atomistic Universe

In the world of empirical data, objects are atomistic. This means the objects of the observation are static entities that can be studied separately. Moreover, since objects are passive, they have no internal relationships or external relationships with other objects or the subject beyond their proximity. In Whitehead's words, the assumption behind empirical science is that reality is made of "unchanging brute matters" that are spread across space.[120]

In process reality, the processes are continuously tangled in interactions and transformation, so observing or studying something in isolation without considering its constant transformation makes little sense. Instead, the observation and data collection process entangle the observer and the observed, so that all controlling measures should be considered and accounted for. The first consequence is the need for transparency in revealing the influences of empirical research. This could mean transparency about the funding and the mandate behind data collection. The second outcome of this entangled reality is to allow voices from the subjects of the study to be included in the research outcome.

Isolating objects in a relational universe

In traditional metaphysics, things have clear divisions. This means one could isolate part of the larger ecosystem or a part of an organic being to study it. However, investigating an entity without its interconnectedness has no place in the process model of reality. Instead, reality is formed and comes into being through interactions and relationships. Thus, nothing can be entirely isolated. This means instead of relying on reduction and isolating the subject from its

[120] Whitehead, *Science and the Modern World*, 17.

environment, an empirical approach should include a systematic study of relevant networks (or nexuses) around a subject.

The Subjective Experience

In traditional metaphysics, only the human observer or researcher possesses subjective experience. In Whitehead's cosmic model, all interactions involve change and decision-making. Here, in this system, even the smallest units of reality have a degree of subjectivity or subjective forms since they have the agency to make decisions in their interactions and becoming process.[121] In a sense, all entities in this universe influence each other. Thus, in a process model, the empirical method should consider the subjective role of other actual entities or societies in an interaction.

Toward Designing a Process-Oriented Approach to AI

Creating and using AI under a process framework means reconsidering the relationships among AI, the subjects of study, and the creators, and reconsidering the role of AI in this network of relationships. Applying process to AI means redefining the nature of AI, the role of AI in decision-making, or how AI-generated outcomes are incorporated and used over time. In the following, I narrow these factors into six design guidelines for creating such a conceptual framework.

[121] Whitehead, *Process and Reality*, 19.

1- Design for a Unified and Changing Universe.

The first step in applying the process model to AI design is to reconsider data, what it is, and how it is collected and processed. In the process reality, nothing is static. As a result, data is dynamic and always changing. This also means that data should always include a factor of time and account for change through interactions. Likewise, data comes from a unified system where all parts continuously interact. In other words, data is always connected and changing over time.

2- Design for a Dynamic Universe

In process ontology, reality is dynamic. Applying this to AI design means anticipating fluctuations and providing a mechanism to read and re-integrate changes from the environment into the AI system. Namely, the cycle of learning, transformation, and interaction is fundamental in an AI design process. This implies that an AI system requires continuous data collection and the integration of feedback from the environment to adapt and adjust based on such responses.

3- Design for a Subjective Reality

Subjective experience is at the centre of process reality. This means all entities have the agency to make choices about interactions with the environment. As a result, designing an AI system within this framework requires considering different players and their points of view. As I discussed earlier, AI design is often techno-centric and excludes the position of minorities and marginalized groups. Similarly, AI systems are regularly designed without considering non-human players such as plants, animals or the natural environment. Designing an AI system for a reality in which all entities can have subjective experience means stepping outside a narrow mindset and considering all players in the system. This would produce an AI system designed with different demographics or physical abilities in mind. In creating a nature-related AI, for example, this design process requires incorporating both human-centred and ecology-centred perspectives in its objectives.

4- Design for Creativity and Novelty

In contrast to traditional metaphysics, Whitehead's reality is a creative universe. Creativity drives changes and forms new experiences in the universe. This creative engine for change absorbs the previous engagements and creates new events to carry out new experiences. Unpredictability, novelty, and change are thus natural parts of this reality. As a result, the AI design in this model should account for unpredictability and change as natural parts of the system.

5- Design for Lived Experience

The process reality is a causal universe and is governed by the "laws of nature" that can be understood through repetition and experience. Over time, exposure and interaction with the environment and using common sense reasoning help humans distinguish causal connections from unrelated associations. However, most AI reasoning is built on finding correlations. Judea Pearl, computer scientist and a winner of the Turing Award, argues that "all the impressive achievements of deep learning amount to just curve fitting."[122] In *the Book of Why: The New Science of Cause and Effect*, Pearl uses the barometer example to clarify this lack of understanding of AI systems. In this case, a barometer records pressure and weather changes and

[122] J. Mark Bishop, "Artificial Intelligence Is Stupid and Causal Reasoning Will Not Fix It," *Frontiers in Psychology* 11 (2021), https://www.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2020.513474.

an AI system looks at the data to identify weather patterns. The AI system uses "reasoning by association" and concludes that a barometer below 1000 millibars means rain.[123] However, if we ask AI to bring rain, it thinks that lowering the barometer will create rain. For a human, the knowledge of how rain is caused comes through habitual insight and is learned through repeated interactions with the environment.

Working with data without causal reasoning means that even the most sophisticated machine learning models are trapped in equating correlation with causation.[124] Since an AI system could never have a lived experience, such human reasoning is forever beyond machine learning. Because of this, Pearl advocates for replacing purely statistical analysis with causal reasoning based on the Structural Causal Model (SCM) framework. This process integrates graphic models or causal graphs, such as Directed Acyclic Graphs (DAG), as AI logic to ensure AI is aware of the direction of associations.[125]

6- Design Driven by Values

In *Process and Reality*, Whitehead expands his earlier writings into theology and the role of the Divine. The Divine presence in Whitehead's system is a single actual entity that does not change or go through the process of becoming. The Divine is the "poet of the world" who leads

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123 Judea Pearl and Dana Mackenzie, *The Book of Why: The New Science of Cause and Effect* (Basic Books, 2018).

124 Sema K. Sgaier et al., "The Case for Causal AI (SSIR)," 2020, https://ssir.org/articles/entry/the_case_for_causal_ai; Jordi Vallverdú, "Causality and Artificial Intelligence," in *Causality for Artificial Intelligence: From a Philosophical Perspective*, ed. Jordi Vallverdú (Springer Nature, 2024), https://doi.org/10.1007/978-981-97-3187-9_2; Bishop, "Artificial Intelligence Is Stupid and Causal Reasoning Will Not Fix It."

125 Judea Pearl, "Graphs, Causality, and Structural Equation Models," *Sociological Methods & Research* 27, no. 2 (1998): 226–84, https://doi.org/10.1177/0049124198027002004; Dan Geiger and Judea Pearl, "On the Logic of Causal Models," arXiv:1304.2355, preprint, arXiv, March 27, 2013, https://doi.org/10.48550/arXiv.1304.2355; Geiger and Pearl, "On the Logic of Causal Models"; Judea Pearl, *An Introduction to Causal Inference*, February 1, 2011, https://escholarship.org/uc/item/5wk4j60p; Philip Dawid, "What Is a Causal Graph?," arXiv:2402.09429, preprint, arXiv, January 24, 2024, https://doi.org/10.48550/arXiv.2402.09429.

the creative process with patience toward "truth, beauty, and goodness."[126] Therefore, the process world is driven by a value system that follows long-term goals. In an AI system based on the process framework, values could reflect ethical and moral ideals or have a different significance, depending on the system's goals. As a result, the PAI design needs to start by clarifying its values and creating safeguards to encourage their implementation.

Conclusion

Guiding AI design through process philosophy means creating an AI system that is connected to the changing environment and is responsive to it. Moreover, by working collaboratively with human agents, AI can be trained through iterations to integrate the non-computational aspect of human knowledge into its work. These could be intuitive understanding, working experience, moral judgement, or the common sense understanding of a situation.

Creating a conceptual framework for guiding AI design requires merging AI's inner workings with process design principles. In the next chapter, I will establish the six main principles for a conceptual framework to re-imagine AI design based on process philosophy. In the next chapter, I define the research-creation methodology for bringing these ideas closer to an operational model.

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[126] Whitehead, *Process and Reality*, 346.

Chapter 3: Methodology

This dissertation builds a conceptual framework to re-imagine AI design through the lens of process philosophy. As discussed in the previous chapter, integrating this process principle with AI design encourages contextual awareness and promotes human-type reasoning in a computational model. As a result, it could detect moral and ethical nuances while implementing common sense thinking patterns. Working within this framework will ultimately allow for designing AI systems that work through collaboration and can move beyond the limitations of data and machine learning. This chapter outlines the methodology I will use, including the conceptual and technical support behind it, and shows how it fits into meeting the goals and requirements of this dissertation.

Reaching a methodology to pursue this dissertation and communicate the outcome has been essential in developing this dissertation. As a result, this chapter establishes the conceptual and technical support behind this methodology. Establishing the methodology in this dissertation required a unique adaptation of existing methods to address the needs and context of this research. Ultimately, this could provide a framework that can be adapted and extended to other applications and set a precedent for future similar studies.

The Case for Research-Creation

The methodology in this research reflects the process model. Whitehead's process is about the underlying interconnected nature of things, and, as a result, shows how different forms of knowledge are inherently linked and connected. This methodology reveals the interconnectedness of process philosophy and computer science. It seeks to find value and insight in the intersection of these two fields and emphasizes the importance of including philosophical ideas alongside technical requirements in AI to start a conversation between the two. In this way, it uses a creative approach to investigate ideas and reach the desired outcome.

My development of this process was inspired by a "method of discovery" described by Whitehead in *Process and Philosophy*. Whitehead describes a "true method of discovery" based on "the play of a free imagination, controlled by the requirements of coherence and logic." This imaginative technique starts from the structure of a "particular topic" and takes a creative turn to move beyond direct observation or logical reasoning.[127] As a result, this approach allows for free speculation, experimentation, and juxtaposition of ideas and possibilities to produce a unique outcome.

For Whitehead, this "method of discovery" requires a measure of success. He writes that "the success of the imaginative experiment is always to be tested by the applicability of its results beyond the restricted locus from which it originated." Consequently, for Whitehead, the success of this "imaginative experiment" is tied to the practicality of its outcome.[128] Using this process approach to discovery, I incorporate imagination and the scientific method into the methodology. To start within the borders of AI design, I take a creative turn to allow for experimentation and later test the findings for their practicality and ultimate success.

Research-Creation for Discovery and Applicability

The conceptual framework for process-based AI design has two parts. In the first part of this methodology, I use a creative process to pull apart the elements of artificial intelligence and align them with the process principles. Later, I use data visualization and concept maps to bridge

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[127] Whitehead, *Process and Reality*, 5–16.

[128] Whitehead, *Process and Reality*, 5.

conceptual ideas with practical requirements for AI design. To carry this out, I create different maps to classify, expand, and establish the theoretical framework.

In the second part, I use the SproutCityTO case study to apply the conceptual process-based framework to guide AI design in a real-life scenario. SproutCityTO is an AI-powered web app aimed at increasing public support and awareness around green spaces in Toronto. The SproutCityTO case study offers a holistic product design for the SproutCityTO App and uses AI to monitor and direct user behaviour. Ultimately, the app improves the connection of the user with the natural environment. Creating this case study tests the applicability of the theoretical framework and brings it closer to a practical system.

Research-Creation for Knowledge and Engagement

The goal of the research-creation approach in this project is to re-imagine AI through process philosophy. The first part of this methodology integrates knowledge and expands it through concept mapping. It works through visual language to integrate knowledge from different disciplines and creates new knowledge through these connections.

With the multi-disciplinary nature of this project, one goal of the methodology is to bridge the gap between disciplines. To achieve this, I use a mapping process to engage with ideas and bridge the gap between different forms of knowledge. With the project audience in mind, the goal is to communicate the theoretical framework without requiring a technical background in computer science or philosophy. In addition, this process allows for connecting ideas from different domains and integrating them to form new knowledge. It addresses communication in a multidisciplinary project and makes the outcome approachable and engaging.

Research and Creation through Iterations

Research-creation in this dissertation works through an iterative process, as both parts contribute equally to expanding the findings and refining them. The goal is to make a framework that is not only conceptual but also applicable and practical. In this method, both the research and creation processes inform one another. Mapping AI design through the process model narrows the process-oriented AI (PAI) to its essential elements. The creative process works with PAI principles to examine their applicability. The insight gained through the repetition of this creative process further refines, expands and adjusts the PAI principles. The final, refined PAI offers a more practical guide for informing AI design. Ultimately, this method mirrors the integrated knowledge and interconnected approach outlined in Whitehead's philosophy.

Direction and Preparation

Working on this multi-disciplinary research, I fully engage with the disciplines of philosophy and computer science. I conduct a close reading of Whitehead's work to identify elements of the process model that I apply to AI. This means working across his body of work and studying the scientific basis of his philosophy in his lecture notes. I needed this level of engagement to grasp the underlying principles in process philosophy and to be able to apply them to data or machine learning.

Similarly, to master the technical aspects of this project, I immersed myself in learning about AI and machine learning and tried real-world scenarios. My background in software development and data analytics gave me leverage here. However, to learn about AI, I participated in a year of classes and workshops to better understand the technology and acquire hands-on experience. To do this, I joined the AI training program offered by Compute Canada and the Digital Research Alliance of Canada to learn about using different machine learning models, Neural Network Programming, and Quantitative Applications with AI.

I also joined the Applied Remote Sensing Training Program (ARSET) offered by NASA to learn about doing AI analysis with satellite imagery of bodies of water and tree canopies.[129] This enabled me to see the possibilities of using AI to solve ecological challenges.

Furthermore, to solidify my knowledge, I participated in a summer data study group at the Alan Turing Institute offered by Leeds University.[130] The program gave me a chance to work as part of a team on a real-life challenge for the UK's Network Rail. The project involved applying AI analysis to aerial imagery and allowed me to learn the technology through hands-on experience in managing its challenges.[131] This process was important in developing the final methodology because it gave me a better understanding of the inner workings of AI, applying process philosophy principles to it and eventually working through to achieve a satisfactory methodology.

In the following, I further divide each step in implementing the process of research and creation. The methodology is applied in two steps: Part A is about identifying and refining the PAI principles; Part B involves making the SproutCityTO case study.

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[129] Applied Remote Sensing Training Program, NASA, https://appliedsciences.nasa.gov/what-we-do/capacity-building/arset

[130] Alan Turing Institute is the UK's national institute for Data Science and Artificial Intelligence.

[131] Siddharth Jha et al., *Automatic Detection of Counterfort Drains*, Data Study Group Final Report: Network Rail (2021), https://www.turing.ac.uk/sites/default/files/2022-04/the_alan_turing_institute_data_study_group_final_report_-_network_rail.pdf.

Part A: Concept Mapping Process-Based Principles

Sage Research Methods defines concept mapping as "a visual representation of the relationships among a set of targeted topics. The goal of concept mapping is to create an actual map where the concepts are represented as nodes, and the relationships between them are represented as lines that link those nodes."[132] Concept maps provide a creative outlet to connect ideas outside a linear structure. They offer an effective tool for communicating ideas in a multidisciplinary context.

In my use of concept mapping, I incorporate shapes, lines, images, and text to visually represent ideas from process philosophy to the inner workings of an AI system. Concept maps can break barriers among disciplines by communicating complex ideas and technical language and by integrating knowledge from multiple disciplines.

Concept mapping is about using visual elements to illustrate ideas and represent their relationships with each other. The process not only simplifies communication but also generates new information by forming new connections. This is a visual method for discovering relationships among ideas and finding new pathways.

The role of a concept map is first to illustrate the existing knowledge and second to use it to construct a new set of connections, concepts, and meanings. Concept maps illustrate the relationship between "concepts we know" to form new links and generate "new propositions" that construct new knowledge and meaning through the process.[133]

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[132] Lisa M. Given, *Sage Research Methods - The SAGE Encyclopedia of Qualitative Research Methods - Concept Mapping* (n.d.), accessed February 11, 2025, https://methods.sagepub.com/ency/edvol/sage-encyc-qualitative-research-methods/chpt/concept-mapping?PageNum=109&token=8782d2fe-89c2-4fea-b9fc-7c4c151c54b45b940347292791c8b26045ff31d28e2da237e72d121a12532ae6cbb04ffaed38.

[133] Joseph Donald Novak and D. B. Gowin, *Learning How to Learn* (Cambridge University Press, 1984), 17.

Joseph D. Novak, the father of concept mapping, defines it as a "technique for externalizing concepts and propositions."[134] In concept mapping, propositions are statements or links that connect different concepts. The process of assigning, re-evaluating, and adjusting these propositions opens the door to critical thinking and the creation of new ideas.

Whitehead writes, "seek simplicity and distrust it."[135] The concept mapping process explains the complex through simplicity, and links ideas to discover new ones. Here, each concept is not just a singular idea but is understood through the interconnected web of its relationship with other ideas. This enables the interrogation of new findings through the web of other information.

In this dissertation, I use concept maps to describe and exemplify the guiding principle of process-oriented AI design. The goal is to determine how to transform AI from a static and isolated system to a dynamic method connected to its environment. To do this, I first lay down the elements of process philosophy as they relate to AI design. The maps not only summarize the elements of process philosophy but also connect each of its principles to the practical components of AI, such as data and machine learning models. Next, I map the inner workings of an AI system and further clarify how each step in the process can be transformed through process principles. Going back and forth between the theory and the maps, I refine the PAI principles that can be adapted to the working of a real-life AI scenario.

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[134] Novak and Gowin, *Learning How to Learn*, 17.

[135] Whitehead, *The Concept of Nature*, 163.

Concept Maps and Active Learning

The concept mapping process also introduces active learning to the audience for this research. Instead of taking a linear path, it creates a more dynamic direction for pursuing different learning paths and engaging with the work based on previous experience and the current knowledge level in the field. That is, it asks the audience to engage with ideas in various ways and to absorb content through different pathways. This presents a method for "discovery learning," which means that the audience selects the information it wants to learn.[136]

The visual diagramming of complex content allows for both fast and slow reading or quick and detailed methods of learning. Moreover, the aesthetic experience contributes to this active engagement by allowing audiences to select and dig deeper into different sections of the map, according to their needs and interests. Ultimately, the concept maps visualize the conceptual framework at the center of this research and provide concrete examples to illustrate how AI design can augment real-life learning through PAI principles.

Part B: SproutCityTO Case Study

This part of the methodology provides a concrete and practical example to illustrate the applicability of the conceptual framework. Using a real-life challenge, it creates a case study in which to apply process principles in AI. The outcome is a holistic product design for a web application, SproutCityTO app, that operates on top of an AI core. It brings together the urban population with the natural environment. SproutCityTO app connects people to the ecology and history of their urban space. It brings the role of nature into public consciousness and ultimately increases stewardship and public support for urban green spaces. The AI core in SproutCityTO

[136] Novak and Gowin, *Learning How to Learn*, 7.

adjusts its offerings according to data and feedback to reach its goal. The holistic product design approach considers user interface and interaction and offers key technical components for data collection and algorithmic changes. In this methodology, the case study and product design work as an evaluative tool to test the conceptual framework developed using concept maps.

The case study takes the PAI principles closer to practical AI implementation. It achieves this by making a holistic product design to refine the PAI principles and improve their applicability. Overall, creating the case study reworks the conceptual framework to consider more practical nuances.

SproutCityTO App

SproutCityTO app relies on social interaction and user engagement to change the relationship between people and nature in city neighbourhoods. Focusing on the location of urban green spaces (UGS) creates a platform for discussion about their beneficial effects and encourages people to develop events and activities that bring them together in nature. Users can find their local parks, leave reviews, and add or participate in various nature-related events. They can learn about their natural landmarks, the ecology and history of their land, and observe the impact of local green spaces on their well-being. The app encourages citizens to take a role in caring for the natural environment, and, finally, it uses the data collected to promote and suggest events, adjusting them according to their effectiveness. Its goal is to increase social connectivity around nature and raise public awareness about its beneficial role in human life. This case study makes this project a stepping stone towards raising climate consciousness and increasing awareness about the importance of nature in day-to-day life.

To summarize: applying PAI principles, the case study asks questions such as, How do these principles inform the early design decisions? What are the goals of the digital product? What kind of big-picture goals are achieved through the app? Whose needs are being addressed by the app? Whose perspective is reflected?

Case Study Design

The case study design in this project could be described as a practice in systems thinking. To elaborate, this is about looking at the making of the app from the big picture, including users' needs, environmental needs, technical issues, the feedback process, impact on the environment and its long-term impact. Systems thinking is a high-level approach to studying a system. It is about looking at a system through its relationship with its users and other elements that it influences.[137]

The term systems thinking was coined by Barry Richmond in 1987 to describe a way of portraying a complex system holistically.[138] Systems thinking is about incorporating multiple perspectives and working with uncertain parameters to identify their dependencies and predict interactions.[139] It requires describing elements, purpose, and their interconnections.[140] The SproutCityTO case study uses systems thinking to create a holistic approach to the SproutCityTO app. This is achieved by combining elements of Information Architecture (IA),

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137 Ross D. Arnold and Jon P. Wade, "A Definition of Systems Thinking: A Systems Approach," *Procedia Computer Science*, 2015 Conference on Systems Engineering Research, vol. 44 (January 2015): 669–78, https://doi.org/10.1016/j.procs.2015.03.050.

138 Arnold and Wade, "A Definition of Systems Thinking."

139 A. Squires et al., "Building a Competency Taxonomy to Guide Experience Acceleration of Lead Program Systems Engineers," April 1, 2011, https://www.semanticscholar.org/paper/Building-a-Competency-Taxonomy-to-Guide-Experience-Squires-Wade/28fe815dd0a30edb7ed2806432e2ee0eeae28598.

140 Arnold and Wade, "A Definition of Systems Thinking."

UX/UI Design, database design, and algorithm strategies to offer a concrete example of a PAI design.

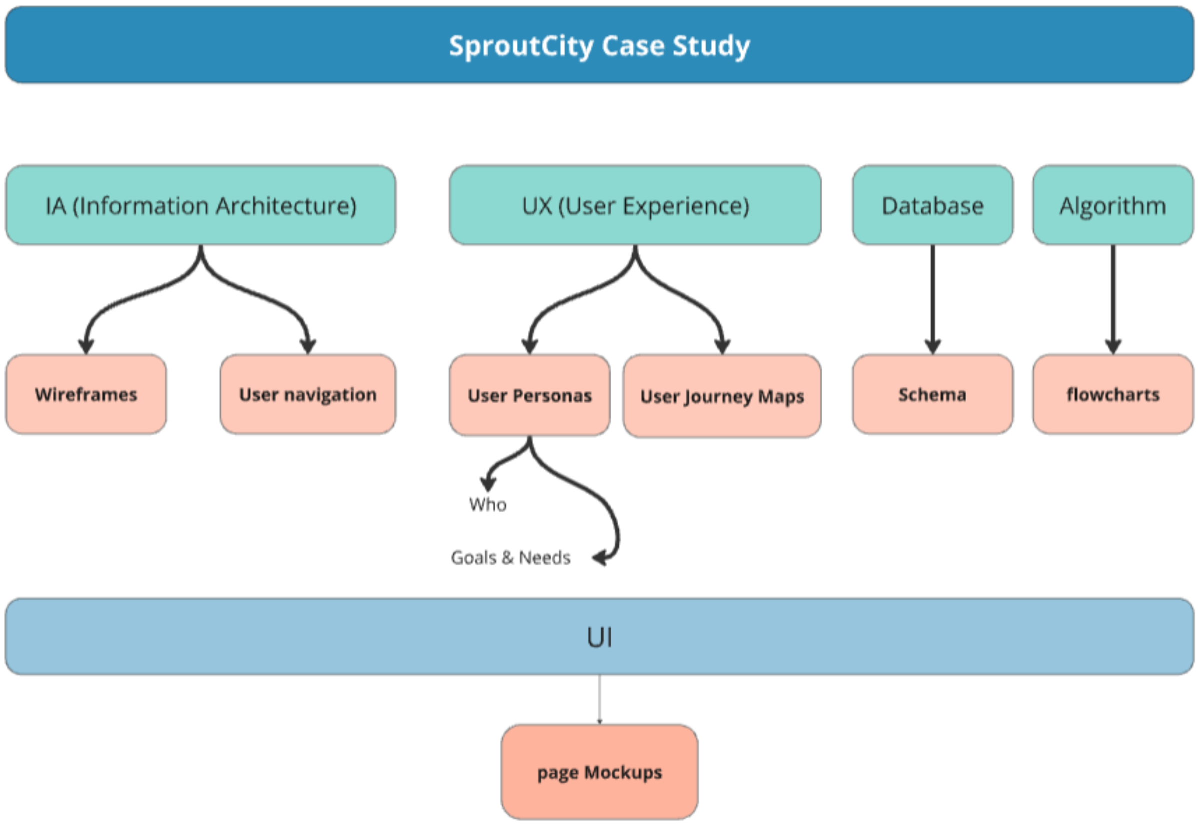

Figure 3. Deliverables

In the following, I examine some elements used in the product design process. Information Architecture (IA) is about thinking systematically about a problem and organizing the outcome into an accessible format. The goal of IA is to make information searchable and easy to navigate. IA could include user navigation or rough sketches of the pages, or wireframes.[141] In this project, designing the app is about defining user interactions and building the overall navigation through mock-up pages.

UI or user interface is the point of interaction between end users and the SproutCityTO system. The case study will design a series of mock-ups to implement the concepts and create a map of key pages in the app. This process identifies pages, interactions, labels, buttons, features, and functionalities meant to be included in the page.

SproutCityTO uses a holistic approach to capture the complexity of relationships between nature and citizens. By bringing together data with the human experience and stories, it combines data analytics with personal and cultural histories to learn and adjust over time.

SproutCityTO increases public awareness about the role of UGS in Toronto and encourages their support through a closer connection between people and their natural environment.

The Question of Urban Green Spaces

The concept map and case study focus on the relationship between city populations and green spaces. Here, we study the dynamics of this relationship. In the following section, we explore the reason behind the importance of this topic and its place in this project.

The methodology in this dissertation unfolds around the relationship between people and nature. Concept maps use a plant to discuss the relational aspect of PAI principles. Similarly, the case study creates an app that improves support and appreciation of the natural environment. As

[141] Louis Rosenfeld et al., *Information Architecture: For the Web and Beyond*, Fourth edition (O'Reilly, 2015), 36–37.

a result, it is important to reflect on why caring for nature and green spaces encourages climate consciousness and initiates grassroots movements to take action on larger climate challenges.

Conclusion

The concept maps and the case study combined are tools for exploring the underlying principles of process-oriented artificial intelligence systems. PAI systems are dynamic, context-aware and handle complex and interconnected situations. This is achieved by accounting for contextual data from the early stages of AI design and incorporating human knowledge that only comes through lived experience within a human body. The methodology in this dissertation combines research and creative practices to extract PAI principles and uses a case study to test its applicability. In the next chapter, using the methodology defined here, I refine and map the principles from Chapter 2 to integrate technical requirements with philosophical ideas and communicate the outcomes.

Chapter 4: Process-Oriented AI (PAI)

In Chapter 2, I examined process philosophy principles and their connection to artificial intelligence and concluded with six guidelines for designing AI based on the process philosophy framework. In this chapter, I unpack and refine these guidelines to clarify and simplify the creation of process-based AI design.

The PAI principles in this chapter are a result of a conversation among Whitehead's ideas and those generated by working on concept maps. Reaching PAI principles involved working through the theoretical ideas to rework the maps by linking technical and theoretical ideas. Some changes were also made after creating the case study in Chapter 5. The PAI principles and the conceptual framework are the outcome of interactions among the concept maps, the SproutCityTO case study, and the process theory.

Process-Oriented AI

Process-oriented AI (PAI) is a conceptual and technical framework for working and solving problems with AI. Its main objective is to mitigate the limitations of traditional AI and empirical reasoning by creating a different working model for the technology. PAI is a collaborative process that iterates between human agents and AI. It incorporates big-picture thinking, causal reasoning, common-sense analysis, embodied knowledge, and a cultural grasp of problem-solving with AI. Built on six principles based on Alfred North Whitehead's philosophy of organism, the PAI framework prioritizes context and relations over individual data points.

This chapter lays out the principles and scaffolding of a process-oriented AI system. The accompanying maps illustrate and expand on these ideas and provide further examples. Working with a process-oriented framework requires rethinking the role of AI and continuous human and

AI collaboration. As I explore further, at the end of this chapter, adopting a process-oriented approach adds context awareness, domain knowledge, inclusivity, moral judgement, ethical sensitivity, and intuitive understanding to AI decision-making.

Venirella Plant Example

To map the theoretical framework and illustrate key ideas, I used a hypothetical Venirella plant along with simulated data to visualize the main concepts in this chapter. The use of this plant works as a small case study and provides a concrete anchor for illustrating ideas and diagramming related concepts. Venirella is a fictional species that grows commonly in urban green spaces. It grows in wet and shady spots and provides food for local wildlife. Having public green spaces along the flood zones makes this a popular plant to spot in the Greater Toronto Area (GTA).

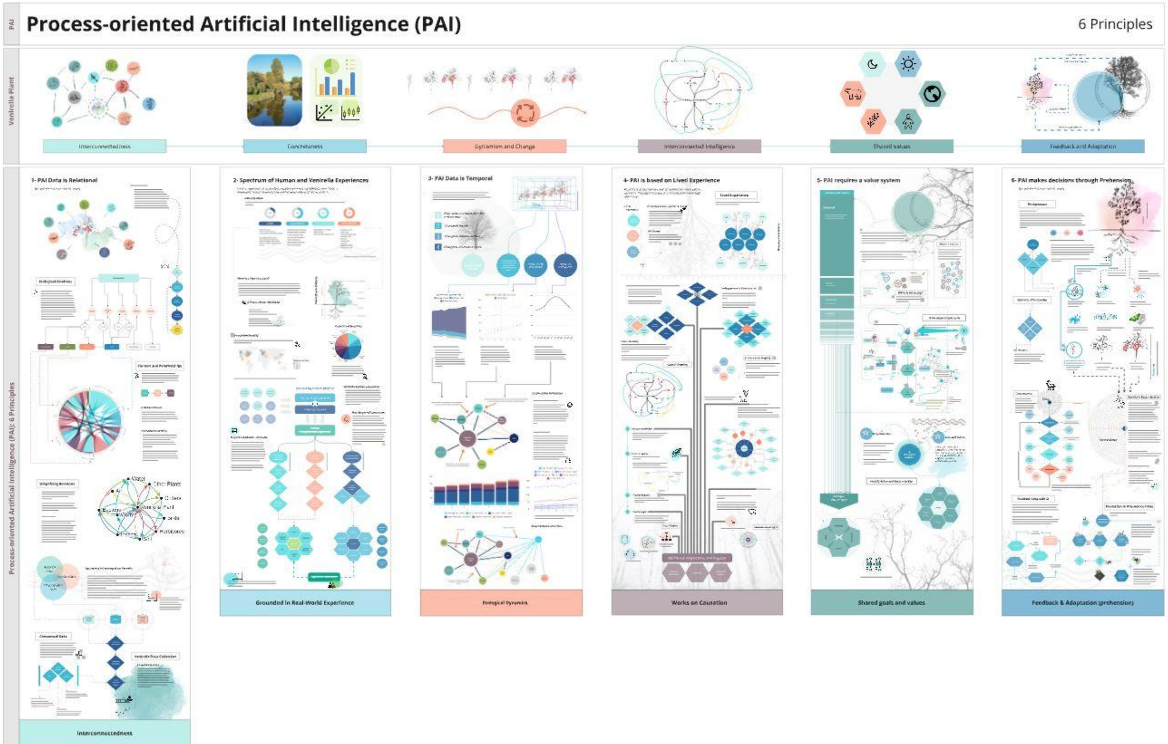

Figure 4. Map I, Six PAI Principles, from Left to Right and Top to Bottom

PAI Principles

In the previous chapter, I summarized AI design principles into six guidelines and concluded that applying process philosophy ideas to data and machine learning must take into account dynamism, relationality, subjectivity, creativity, experience, and values. In the following, I expand and refine these guidelines into six principles. The mapping process allows for the investigation of each principle and connects it to the corresponding technical requirements in AI and real life.

PAI Principle 1: Interconnectedness

One of the key components of the process universe is the idea of wholeness. In this model, entities exist not as separate or 'atomistic' beings, but as internally connected and constantly interacting entities.[142] They live within a larger organism that exists in "an incompletion in process of production," as it changes and evolves.[143] Like an organism, the smallest component can act independently yet work in tandem with other entities in the system. Equally, the process reality is an ecosystem of different parts, each interacting, making decisions, and changing.[144]

Whitehead's perspective on interconnectedness reflects what theoretical physicist David Tong refers to as the bubbling soup, a fluid-like substance that spreads throughout all of space and contains all that there is.[145] In this quantum soup, even a rock is in a constant state of vibration.[146] In *Reality Is Not What It Seems: The Journey to Quantum Gravity*, theoretical physicist Carlo Rovelli argues that this bubbling soup contains quantum processes that interact to create matter and life.[147] Considering reality as an interconnected mesh of processes gives a different meaning to analyzing something through AI. Expanding this principle and mapping it for the Venirella plant means starting the study by examining the plant's relationships to its environment and understanding the complexities involved.

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[142] Here the term 'atomistic' reflects Whitehead's interpretation of the Newtonian dualistic assumption that physical objects exist individually, with simple external relationship to other objects. The term is used in contrast to events or actual entities that have internal connections to other entities and exist in the continuity of an interconnected universe with internal connections.

[143] Whitehead, *Process and Reality*, 214.

[144] Whitehead, *Process and Reality*, 167.

[145] "David Tong -- What Is Quantum Field Theory?" accessed January 24, 2024, https://www.damtp.cam.ac.uk/user/tong/whatisqft.html.

[146] Carlo Rovelli, *Reality Is Not What It Seems: The Journey to Quantum Gravity* (Allen Lane, 2016), 117.

[147] Rovelli, *Reality Is Not What It Seems*, 120.

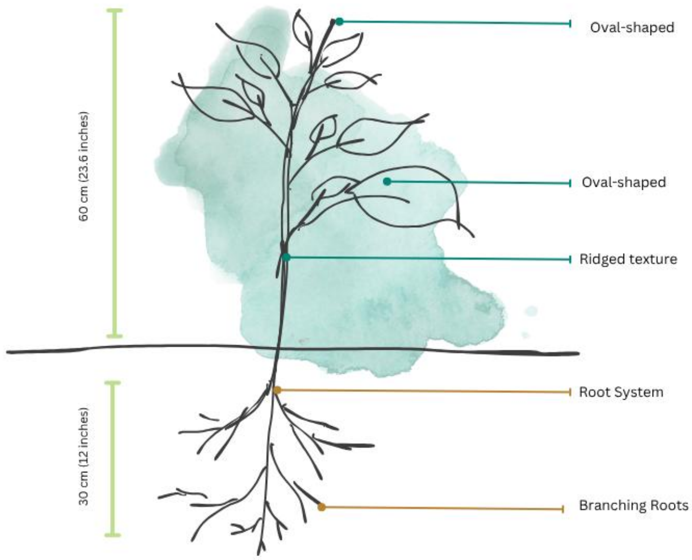
Observation is Conversation

All AI systems are currently built on empirical observation and data. In a traditional empirical model, data is collected from a phenomenon or object. All data points reveal information collected through this procedure. The object of the study is passive and plays no role in this method. In the process model, collecting data involves more than receiving external facts. For Whitehead, data is information exchanged between events, since events can create a response in their observer.[148] Consequently, process data is a mode of exchange between entities, including both conscious and non-conscious beings. This definition is aligned with Marshall McLuhan's idea of information in the "electric information environment." This type of data is not a fixed point of measurement. Rather, it is transient and participatory, as it is being exchanged in the environment. Thus, from the process standpoint, data is an exchange of information between different parts of a unified system. In the PAI framework, this translates to the first design principle: Data is relational.

AI Design Point: Data is Relational

In a traditional AI system, data needs to be gathered, cleaned, processed, and finally sent to the AI machine for training ML models. This data provides the basis for finding trends and patterns in the outcomes. For instance, to study the growth of a hypothetical Venirella plant using traditional AI, data about Venirella plants is collected to predict future trends in its development. The information about a Venirella plant could look like the following:

[148] Isabelle Stengers, *Thinking with Whitehead: A Free and Wild Creation of Concepts*, First Harvard University Press paperback edition, trans. Michael Chase (Harvard University Press, 2014), 269; Whitehead, *Process and Reality*, 88.



Plant Name	Venirella
Classification	hypothetical plant
Root Structure	branching roots
Root Type	fiberous
Root Color	brown
Leaf Type	oval-shaped
Leaf Size	15 cm
Vein Pattern	palmate

Figure 5. Hypothetical Venirella Plant Measurements

This collected data is often stored in a tabular format, such as the following example:

ID	Common Name	Scientific Name	Latitude	Longitude	Leaf Shape	Leaf Size (cm)	Root Structure	Fruit Yield	Max Height (m)	Flowering Season	Region
1	Venirella Moss	Venirella	43.6532	-79.3832	Oval	8–10	Fibrous	Low	0.5	Spring	Toronto, Canada
2	Shadow Fern	Venirella	40.7128	-74.006	Oval	6–9	Rhizomatic	None	0.7	Summer	New York, USA
3	Cityleaf	Venirella	34.0522	-118.2437	Oval	10–12	Taproot	Moderate	1.2	Late Summer	Los Angeles, USA
4	Urban Weaveleaf	Venirella	51.5074	-0.1278	Oval	7–11	Fibrous	Low	0.9	Spring	London, UK
5	Parkside Vine	Venirella	48.8566	2.3522	Oval	5–8	Fibrous	None	0.6	Spring	Paris, France
6	Quiet Bloom	Venirella	35.6895	139.6917	Oval	9–12	Rhizomatic	High	1.1	Early Summer	Tokyo, Japan
7	Greenshade	Venirella	-33.8688	151.2093	Oval	6–9	Fibrous	Moderate	1	Spring	Sydney, Australia
8	Stonepath Creeper	Venirella	55.7558	37.6173	Oval	7–10	Rhizomatic	Low	0.8	Late Spring	Moscow, Russia
9	Courtyard Fern	Venirella	19.4326	-99.1332	Oval	10–13	Taproot	Moderate	1.3	Rainy Season	Mexico City, Mexico
10	Shade Nest	Venirella	-1.2921	36.8219	Oval	9–11	Rhizomatic	Low	1.1	Wet Season	Nairobi, Kenya
11	Metro Moss	Venirella	37.7749	-122.4194	Oval	8–10	Fibrous	None	0.7	Summer	San Francisco, USA
12	Deepshade Root	Venirella	52.52	13.405	Oval	6–8	Taproot	Low	0.6	Spring	Berlin, Germany
13	Rainpatch Bloom	Venirella	-23.5505	-46.6333	Oval	11–13	Fibrous	Moderate	1.2	Late Summer	São Paulo, Brazil
14	Roofedge Leaf	Venirella	1.3521	103.8198	Oval	10–12	Rhizomatic	Moderate	1	Monsoon Season	Singapore
15	Wall Fern	Venirella	41.9028	12.4964	Oval	8–9	Taproot	Low	0.9	Spring	Rome, Italy
16	Alley Bloom	Venirella	31.2304	121.4737	Oval	6–10	Fibrous	Moderate	1.1	Summer	Shanghai, China
17	Shade Basketleaf	Venirella	30.0444	31.2357	Oval	9–11	Taproot	Moderate	1.2	Spring	Cairo, Egypt
18	Balcony Creeper	Venirella	37.9838	23.7275	Oval	7–10	Rhizomatic	Low	1	Early Summer	Athens, Greece
19	Railshade Vine	Venirella	-34.6037	-58.3816	Oval	10–13	Fibrous	Moderate	1.3	Fall	Buenos Aires, Argentina
20	Brickfern	Venirella	45.5017	-73.5673	Oval	6–8	Rhizomatic	None	0.8	Spring	Montreal, Canada

Figure 6. Sample Data of Venirella Plants Collected Worldwide

This information, along with other tables, is then used for AI analysis and machine learning. These traditional data models work based on fixed schemas to store information about plants, such as size, shape, and colour. In the process model, studying the same Venirella plant starts with the idea of one organism. This requires including context and the environment from the beginning of the observation and data collection. Under the PAI framework, we start with understanding the big picture and the ecological network surrounding the Venirella plant. Since a Venirella plant is not entirely defined by its characteristics or reactions to its environment, we start by exploring its larger surroundings, such as other vegetation, animals, insects, bodies of underground water, and the air surrounding the plant.

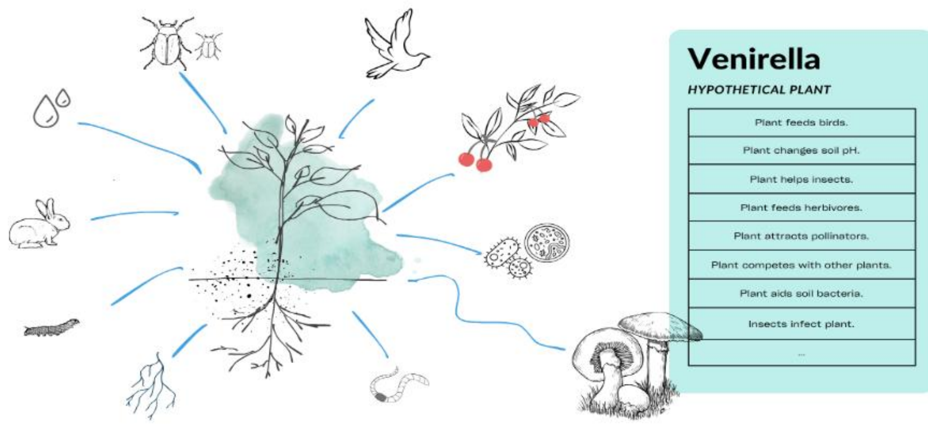


Figure 7. Venirella Plant Relationship

Knowing that a Venirella plant represents only a portion of a larger system means that we need to start with the big picture. Here, data collection starts by mapping the plant’s interconnected network. This means considering the plant’s relationships and connections to its larger ecosystem.

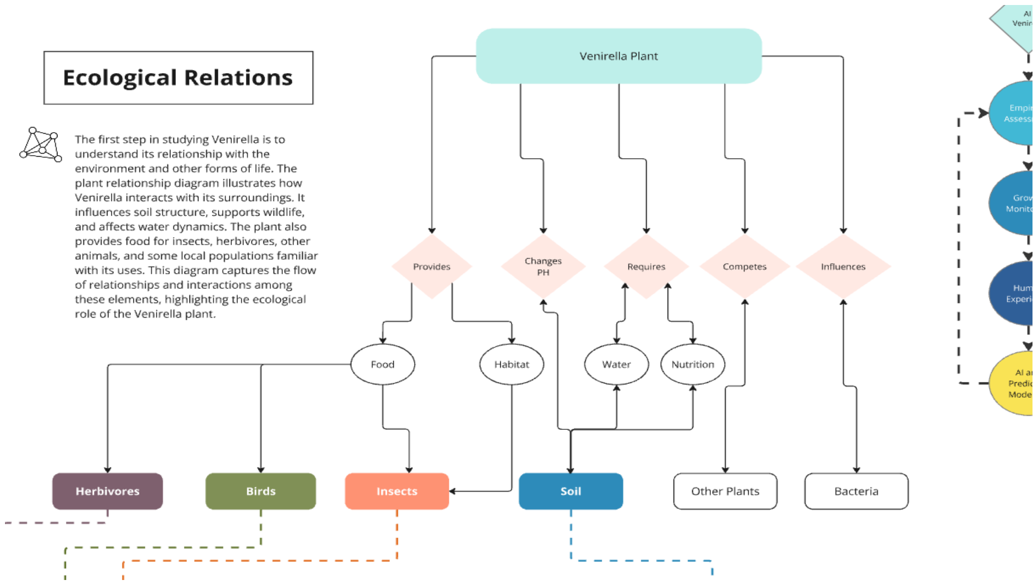


Figure 8. Venirella Plant and Its Relationships

Identifying Connections

Studying an object or a scenario starts by looking at its external relationships and identifying them. Looking at AI through this process means focusing on the interconnected happenings under the structure. For instance, in collecting data to study the Venirella plant, we start by considering these questions: What are the immediate relationships to this plant? What type of connections do they define? What are the relevant links to the study question? How is it possible to quantify them?

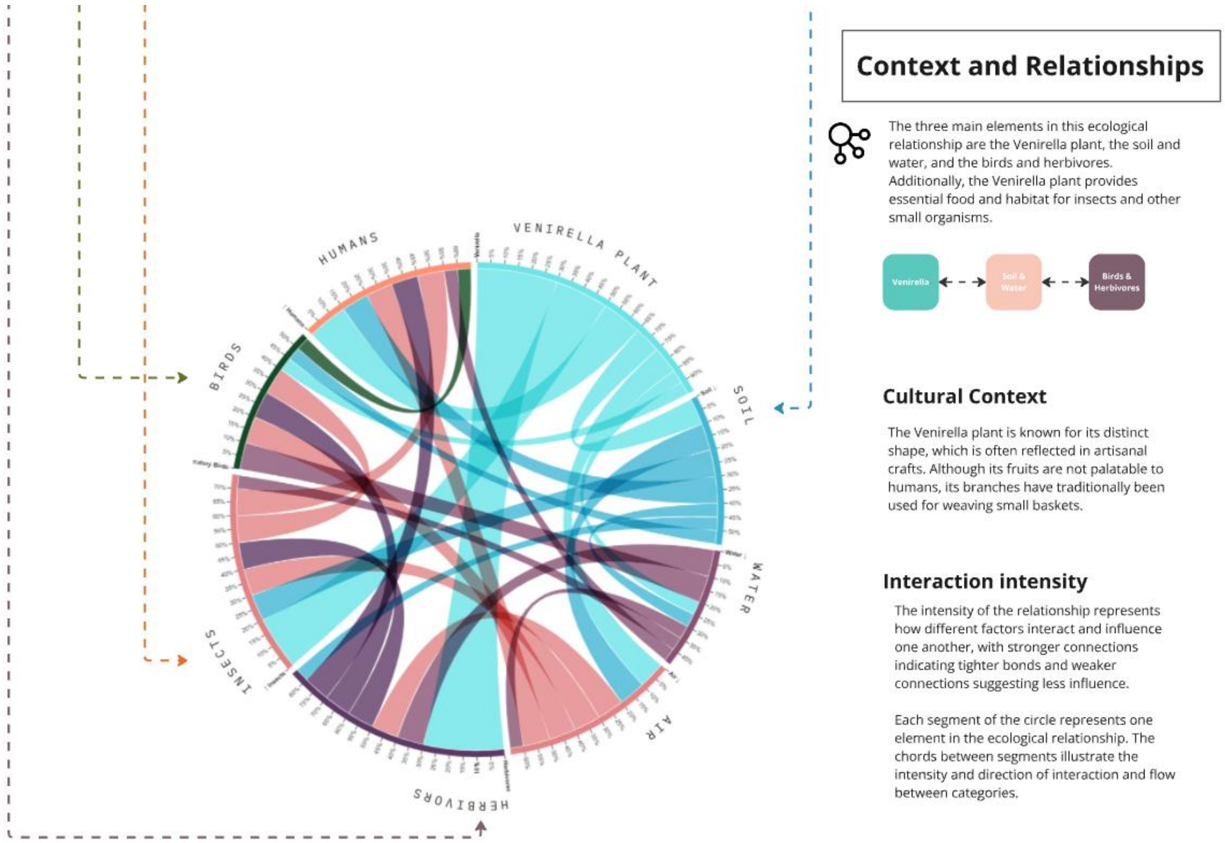


Figure 9. Quantifying Relationships and Interaction Intensity

The next step is quantifying the relationships and giving weight to them in terms of how much they influence the growth of the Venirella plant. In this example, data visualizations represent the degree and connectivity of the plant to different elements in its environment.

Mapping Relationships

Identifying relationships also means that alternative forms of data, such as heuristic data and local knowledge about the plant, can be mapped as part of the relationship.

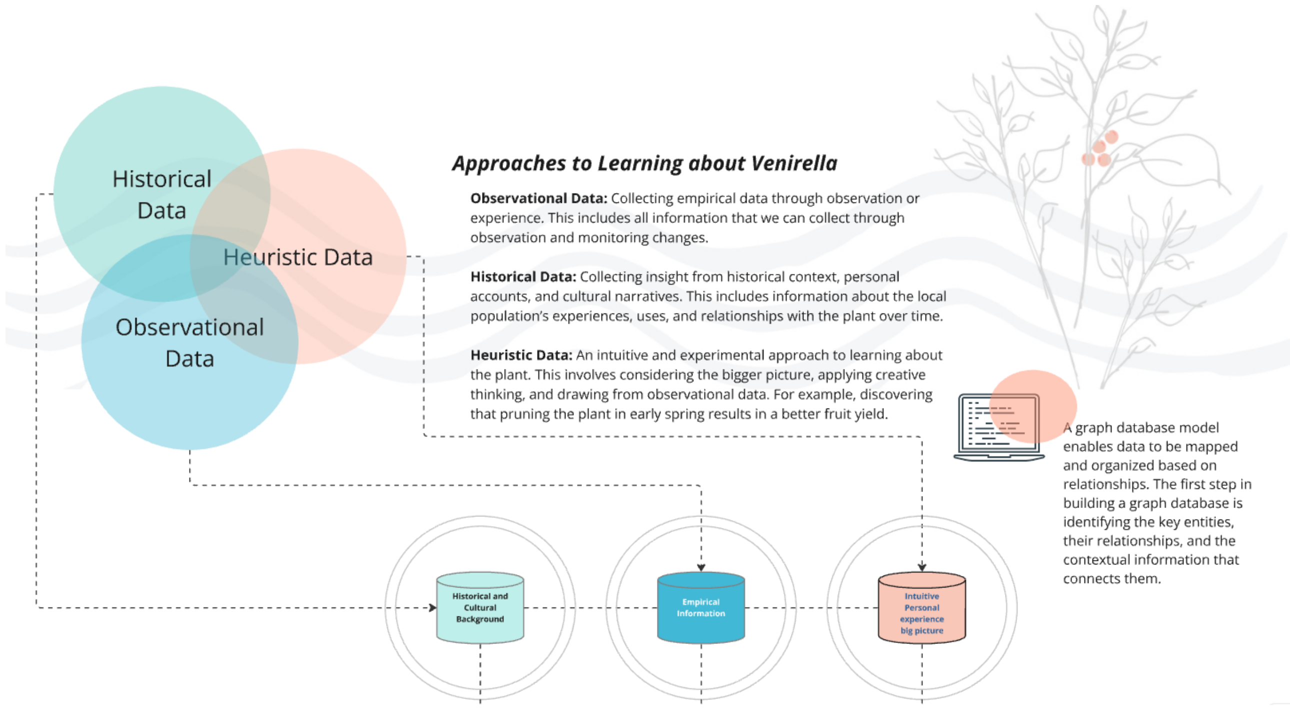


Figure 10. Different Types of Data

A graph data model offers a flexible way of representing different elements (nodes) and their relationships (edges). Unlike the fixed schema model, connections can be stored and expanded in this data model. Replacing the elements with the name characteristics and relations results in a relational graph as in the following image. A relational graph maps the interconnected elements and their associations. Here, nodes represent different elements in the environment, and the lines represent their relationships.

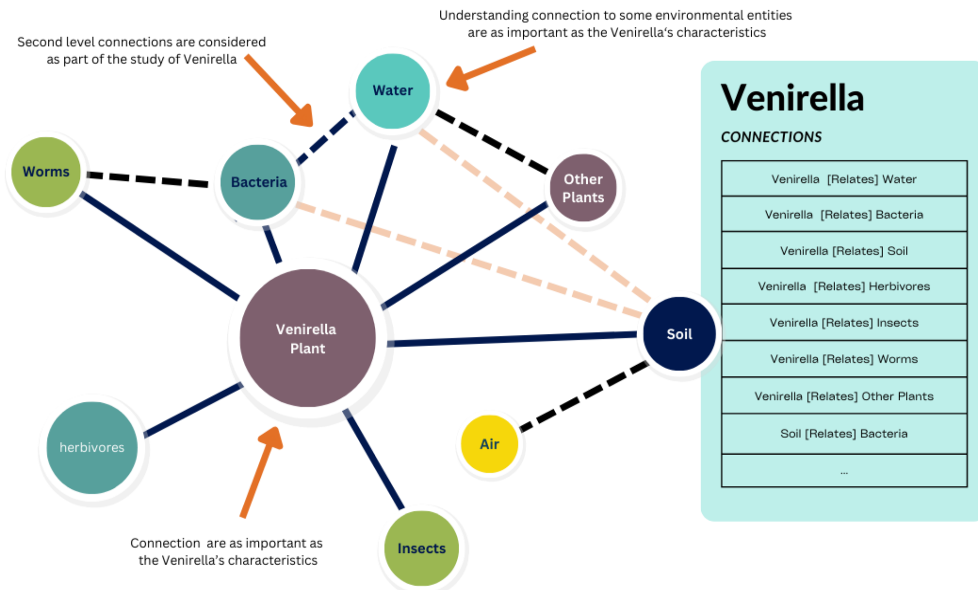


Figure 11. Map of Relations for Venirella.

This could be refined further, so each relationship is identified to mark the type of its interactions in this network. This outcome can be translated into a node graph database, such as Neo4j, using the Cypher language.

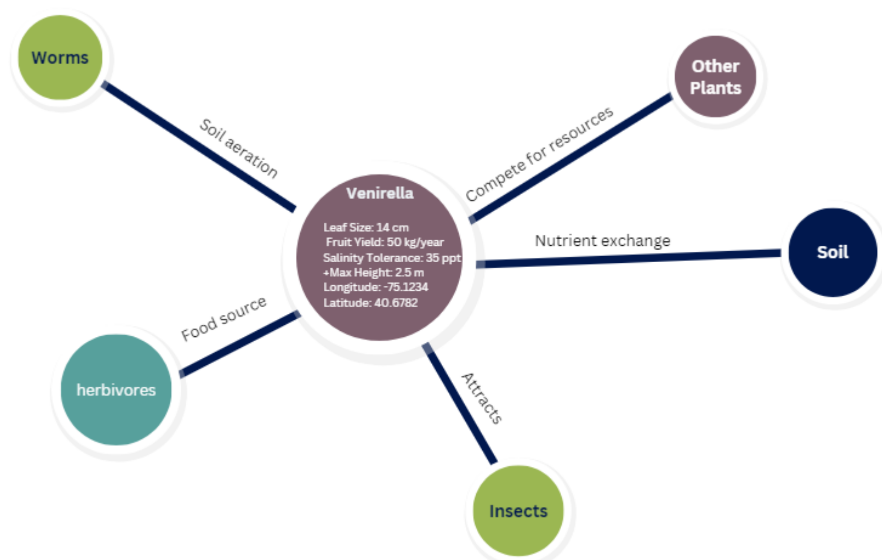


Figure 12. Venirella Nodes and Line Graph.

PAI Principle 2: Data Reflects the Concrete Experience

"The intolerant use of abstractions is the major vice of the intellect."

—A.N.Whitehead

Data is Abstract

At its core, machine learning is about the "systematic discovery of statistically significant patterns" in data.[149] In theory, applying this capability to social and statistical data can portray an accurate map of reality. However, such "logical lenses of machine learning embody faults and biases."[150] The data used in the empirical process is always abstract since it reduces something real into non-concrete measures. Abstract knowledge stands in opposition to concrete and real human experiences.

By communicating human experiences through data, abstraction results in losing related context and details. Here, concreteness is the opposite of abstraction and refers to the actual and lived experiences, which include interactions. Since the world of process is made of events, concrete experiences represent the flow of events. In Whitehead's process philosophy, the concreteness of reality emerges from direct personal experience, which is tied to emotional, social, cultural, aesthetic, moral, and ethical experiences.[151] On the other hand, abstract data are stripped of their emotional and lived experience and instead offer a simplified point of measurement as a reference. For example, the personal experience of seeing the Venirella plant

[149] Parth Bhavsar et al., "Chapter 12 - Machine Learning in Transportation Data Analytics," in *Data Analytics for Intelligent Transportation Systems*, ed. Mashrur Chowdhury et al. (Elsevier, 2017), https://doi.org/10.1016/B978-0-12-809715-1.00012-2.

[150] Pasquinelli and Joler, "The Nooscope Manifested."

[151] Whitehead, *Process and Reality*, 18–19.

in full bloom is reduced to measurements of the size, shape, colour or number of petals on the flowers. No mention of its beauty or effect on the beholder is possible using abstract data.

Degrees of Abstraction

Here, the experience of the Venirella plant is represented through various types of data, from an analysis of the nutritional value of the Venirella fruit to information about its density and a poetic expression about the plant. Colour, for instance, is a highly abstract characteristic of a flower. In contrast, an experiential moment, such as feeling joy when seeing the colour of a flower, is concrete. The following diagram presents degrees of abstraction, ranging from a concrete experience to an abstract value.

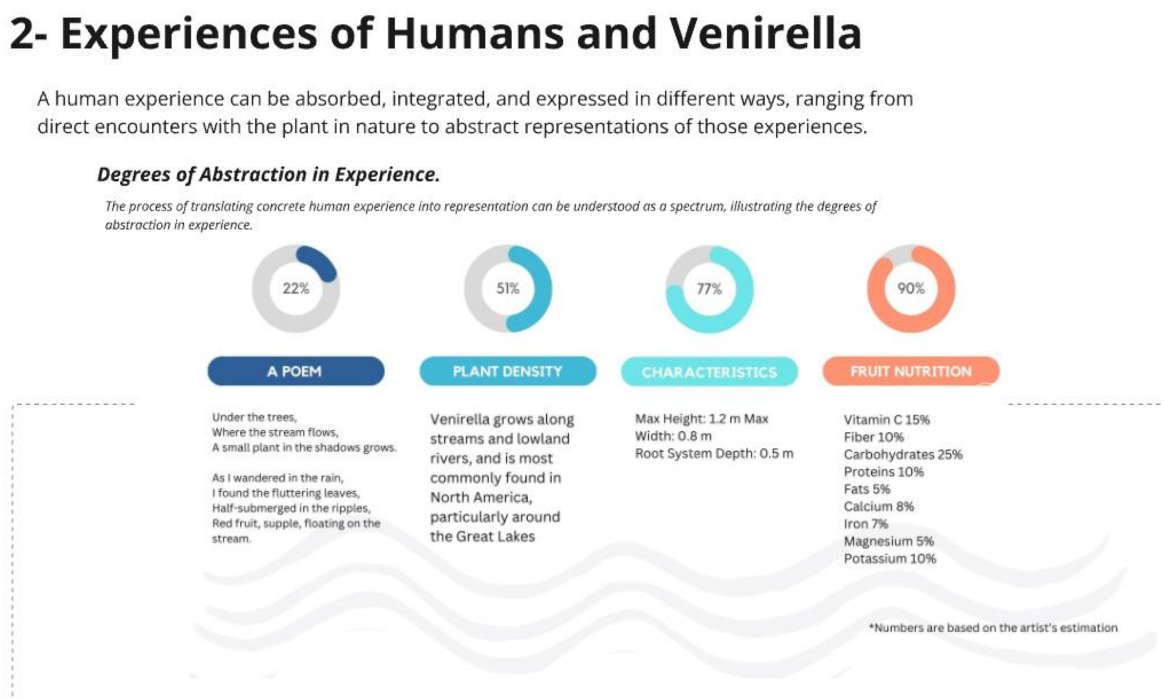


Figure 13. Degrees of Abstraction

As a mathematician, Whitehead was familiar with "the mathematical treatment of abstractions"[152] and expressed the idea that "no entity can be conceived in complete abstraction from the system of the universe."[153] Therefore, he found it important to understand the "degrees of abstraction" in analyzing an experience. The "degrees of abstraction" appear on a spectrum. For example, creative expression, such as the "poetic insight of an artist," is the closest to concrete experience because poems are aesthetic and allow one to sense the complexity of a happening through emotions.[154]

AI Design Point: Integrate Concrete Data

In traditional AI, most data is abstract. It often represents a generalized value from a single point in time. For instance, the experience of seeing Venirella in full bloom is considered a concrete experience. However, simply knowing information about the size, shape, and colour of the Venirella flowers will not be of equal value to actually seeing them in bloom.

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[152] John B Cobb, *Whitehead Word Book: A Glossary with Alphabetical Index to Technical Terms in Process and Reality* (Process Century Press, 2015), 15.

[153] Whitehead, *Process and Reality*, 7.

[154] Whitehead, *Process and Reality*, 9.

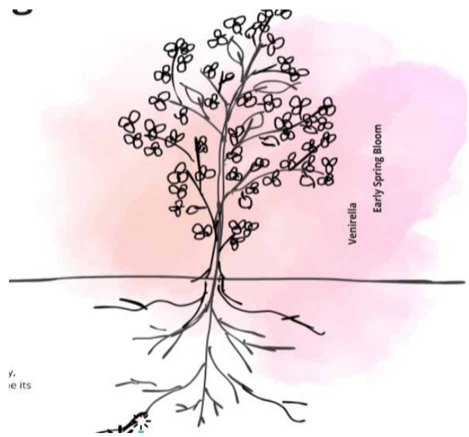

Figure 14. Venirella Plant in Full Bloom.

One possibility to rectify the problem of abstraction through machine learning is to introduce a "witness against the abstraction" or to bring in the voices of the subjects of the study. As Barbara McClintock writes, this involves: "listening to what corn has [to] say"[155].

Working within the PAI framework, the main concern of the third principle is to include as much of the concrete experience as possible. This intervention could mean incorporating qualitative data, such as long-form text, audio, and images, alongside the empirical data. It could also mean incorporating a set of collaborative structures to reintroduce domain knowledge into the AI outcomes.

In the PAI framework, empirical reasoning must be accompanied by layers of concrete reality alongside data-driven analysis.[156] In this context, overcoming the challenges of abstraction and focusing on individual human experiences, such as narratives, creative expressions, images, and poetry, can bring concrete elements of human experience into abstract data and reasoning.

[155] Stengers, *Thinking with Whitehead*, 177.

[156] Whitehead, *Science and the Modern World*, 17.

Stories have been used for centuries to communicate knowledge and insight among generations and to represent a less abstract version of human experience. Instead of relying on generalization, stories often focus on details, names, characters, locations, and settings. Moreover, stories can convey emotions and express the fears, motivations, hopes, and dreams of their characters to connect with their audience. Thus, in PAI outcomes, incorporating narratives and personal expressions alongside statistical outcomes and data visualization can offer a more lasting impact.

PAI Principal 3: AI is Dynamic

Continuous Change and Dynamism

The philosophy of organisms establishes a foundation for a world that is always changing and transforming. As time goes by, every "actual entity" in this universe interacts with the environment and other entities. This means the observation process is also embedded in time and evolves over time. Accordingly, process observation is a continuous act that integrates the traditional collection of data with constant feedback from the environment.

AI Design Point: Dynamic AI System

Most AI models are trained using a fixed database. Each record is collected at a point in time and is treated as a discrete and unchanging entity in the AI system. However, treating AI as an organism requires a dynamic and evolving data model for training, since an organism is constantly learning through new data input. Thus, an AI model requires continuous input of new data to adjust its learning outcome. This could happen by incorporating feedback mechanisms and ongoing training in machine learning models. For example, Reinforcement Learning is a learning model based on trial and error. It introduces rewards and punishments to guide the learning process in an AI system and can be used to fulfill the need for feedback coordination.[157]

The notion of an organism also implies an interplay between parts and the whole. Just as organisms consist of individual components that function both independently and in collaboration with others, AI models could be designed to accommodate this dynamic interplay. For example, using modular architecture could add flexibility to the design and allow readjusting and modifying parts of the system, without requiring its entire redesign.

A modular system not only allows for easier modification and updates, but it can also help with designing more complex models by introducing "engineering hybrid AI systems out of reusable components."[158] The literature in recent years has seen a surge in "hybrid neuro-symbolic AI systems." This entails using architecture to compose only a small set of elementary patterns as building blocks."[159] Embracing the wholeness and organic nature of AI encourages the development of AI models that are more adaptive, responsive, and reflective of the dynamic nature of the world around us.

Allowing AI to learn, adapt, and evolve in the environment adds responsiveness and accountability by design. Relying on a continuous flow of information and learning through a feedback mechanism allows for correction and long-term adaptability. This makes it easier to learn from new factors in the environment and removes errors and biases from the decision-making process as they arise.

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[157] Andrew G. Barto, "Chapter 2 - Reinforcement Learning," in *Neural Systems for Control*, ed. Omid Omidvar and David L. Elliott (Academic Press, 1997), https://doi.org/10.1016/B978-012526430-3/50003-9.

[158] Kamil Wołoszyn et al., "AI4U: Modular Framework for AI Application Design," in *Digital Interaction and Machine Intelligence*, ed. Cezary Biele et al., Lecture Notes in Networks and Systems (Springer Nature Switzerland, 2023), https://doi.org/10.1007/978-3-031-37649-8_6.

[159] Michael van Bekkum et al., "Modular Design Patterns for Hybrid Learning and Reasoning Systems," *Applied Intelligence* 51, no. 9 (2021): 6528–46, https://doi.org/10.1007/s10489-021-02394-3.

Similarly, a modular design presents a more resilient strategy that allows for implementing changes and updates as new conditions are learned from the environment. Changes in input from the environment are adapted by adding or removing them from the modular design. A dynamic AI model also means that an AI system is never complete. It is continually in the process of learning and modifying itself.

AI Design Point: Dynamic Data

Similarly, data in a dynamic system is subject to change over time, which means that most PAI data must incorporate a factor of time. This has two consequences: first, data collection is a continuous process and cannot be limited to a specific time. Second, the AI system should account for change over time and anticipate it. This means that data for process-oriented AI must anticipate change and support continuous learning and feedback from the environment.

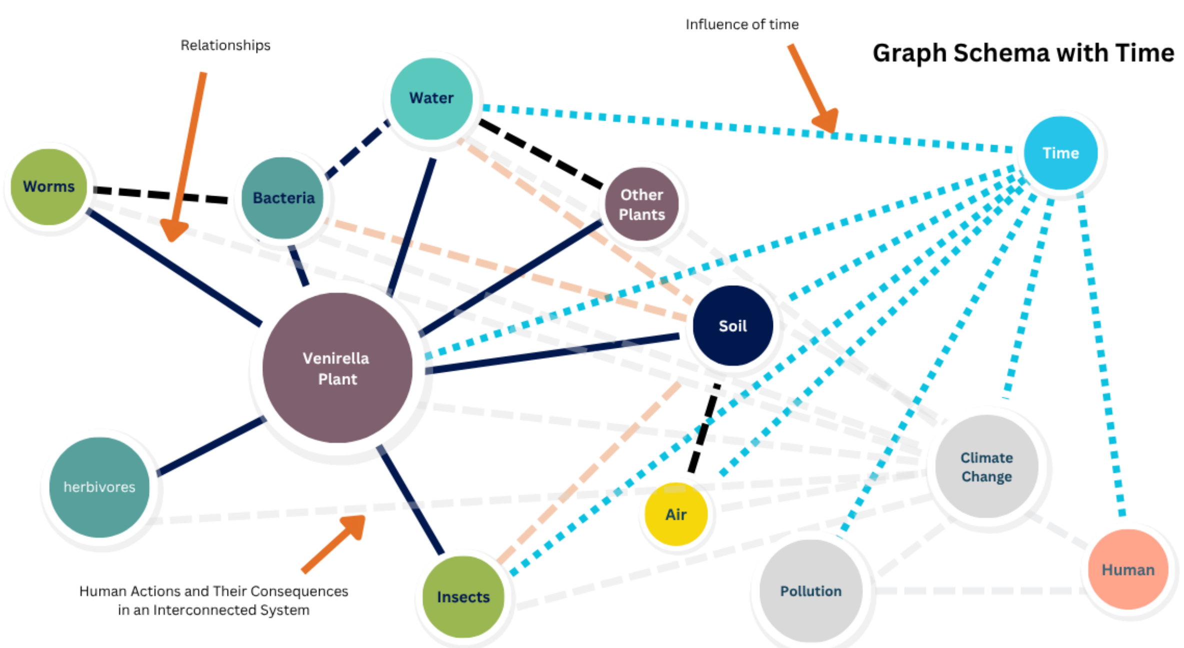

Figure 15. Adding the Element of Time to the Venirella Data

In the accompanying graph, the element of time is added through an extra node to the Venirella graph data. Since all data has a time factor, the changes in the plant size and in the environment are recorded over time.

PAI Principle 4: Human Experience

Whitehead argues that causal reasoning works through direct experience. Whitehead expresses that: "The order of nature cannot be justified by the mere observation of nature. For there is nothing in the present fact which inherently refers either to the past or to the future. It looks, therefore, as though memory, as well as induction, would fail to find any justification within nature itself."[160] He calls this a sense of knowing through lived experience or "faith in the order of nature." Faith in the order of nature is the reason why we understand the underlying harmony behind the sequence of events in nature. For example, we know how the sun changes the temperature on a thermometer and not the other way around.

Knowing through direct experience is learning through "pre-analytic knowledge." For this reason, exposure over time and lived experience help humans distinguish causal connections and understand common sense. Absorbing the underlying harmony of the universe allows the induction process to point to causal relations. This is what Whitehead means by "the order of nature." These could be as simple as associating loud noise with danger or learning how to read body language.[161]

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[160] Whitehead, *Science and the Modern World*, 51.

[161] Ivor Leclerc, *The Relevance of Whitehead: Philosophical Essays in Commemoration of the Centenary of the Birth of Alfred North Whitehead* (Routledge, 2014), 87, https://doi.org/10.4324/9781315830186; Holmes, "A History of Philosophy | 61 Whitehead's Process Philosophy."

These ideas could be expanded to social aspects of people's lives and how we function in different circumstances. Direct experience is first-hand knowledge of the world through our senses, emotions, and intuitions and is reflected in cultural and ethical values, religion, and narratives. We often refer to this as common-sense understanding, causal relations, and moral and ethical judgment. Some elements of the human experience are not always explicable through logical reasoning and thus are not computable.

Machine learning and direct experience

The machine learning process is about using data to infer general rules.[162] Thus, reasoning in machine learning models cannot point to the directionality behind its conclusions.[163] Since machines cannot experience lived, embodied experience, they cannot understand knowledge directly but only through correlation.

Mapping Direct Experience

Collaboration is one of the key foundations of the PAI framework. The PAI framework works with human agents to create and transfer maps of such relationships to an AI system. Abilities such as common sense and causal reasoning come to humans through their lived experience. By adding different perception maps to the machine and defining directionality and associations, we can create a PAI framework that can gradually integrate these connections.

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[162] Raymond J. Mooney, "Integrating Abduction and Induction in Machine Learning," in *Abduction and Induction: Essays on Their Relation and Integration*, ed. Peter A. Flach and Antonis C. Kakas, Applied Logic Series (Springer Netherlands, 2000), https://doi.org/10.1007/978-94-017-0606-3_12; Bruce Nielson and Daniel C. Elton, "Induction, Popper, and Machine Learning," arXiv:2110.00840, preprint, arXiv, October 2, 2021, http://arxiv.org/abs/2110.00840.

[163] Timothy Shanahan, *Deductive and Inductive Arguments | Internet Encyclopedia of Philosophy*, 2024, https://iep.utm.edu/deductive-inductive-arguments/.

Using diverse human agents to generate these maps ensures that different voices are included in the AI design process.

AI Design Point: Mapping Relations

In the following, we explore how the PAI framework incorporates these causal and common-sense experiences through different workarounds. In the following map, each node represents a possibility, and the direction of the lines defines what comes first. A causal diagram maps the causations and the sequence of interactions. Causal maps are often used to understand complex organizations, develop a collective understanding, and identify cause and effect in their structure.[164] A causal map can identify players in a system and determine what factors are linked and in what sequence. Looking at the PAI framework map and charting causal connections involves identifying how different players in the environment influence the growth of a Venirella plant and in what direction.

[164] Gregg M. Burgess et al., "The Application of Causal Maps to Develop a Collective Understanding of Complex Organizational Contexts in Requirements Analysis," *Accounting, Management and Information Technologies* 2, no. 3 (1992): 143–64, https://doi.org/10.1016/0959-8022(92)90013-I.

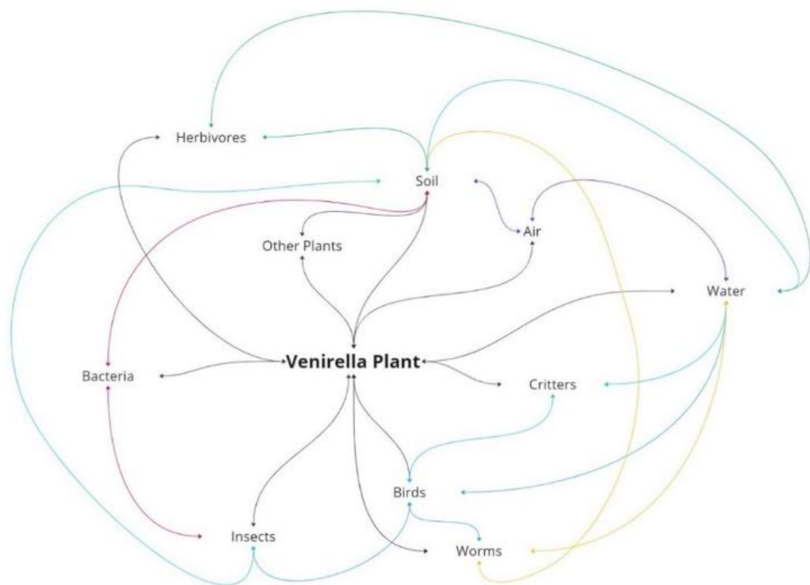

Figure 16. Venirella Plant and Causal Relations.

This diagram can be added to an AI system with a causal engine. Recently, there has been a growing movement toward creating causal engines.[165] These engines are custom-built algorithms that integrate with an AI system to manage and interpret causal inferences directly.[166]

A similar process could be applied to add common-sense reasoning to an AI system. A common-sense diagram represents practical knowledge and relationships in a system. For example, a 'fuzzy cognitive map' could be used to transfer and quantify common sense into an AI system.[167] In a typical fuzzy cognitive map (FCM), weights indicate the strength and type of relationships, or they incorporate uncertainties to quantify the strength of the relationship for

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[165] *Causal Models in Machine Learning*, directed by The TWIML AI Podcast with Sam Charrington, 2020, https://www.youtube.com/watch?v=MuR2eS2QPMI.

[166] *Causal Models in Machine Learning*.

[167] Vijay Mago et al., "Analyzing the Impact of Social Factors on Homelessness: A Fuzzy Cognitive Map Approach," *BMC Medical Informatics and Decision Making* 13 (August 2013): 94, https://doi.org/10.1186/1472-6947-13-94.

later processing through an engine. The following demonstrates an FCM example describing the relationship between the Venirella plant and its environment.

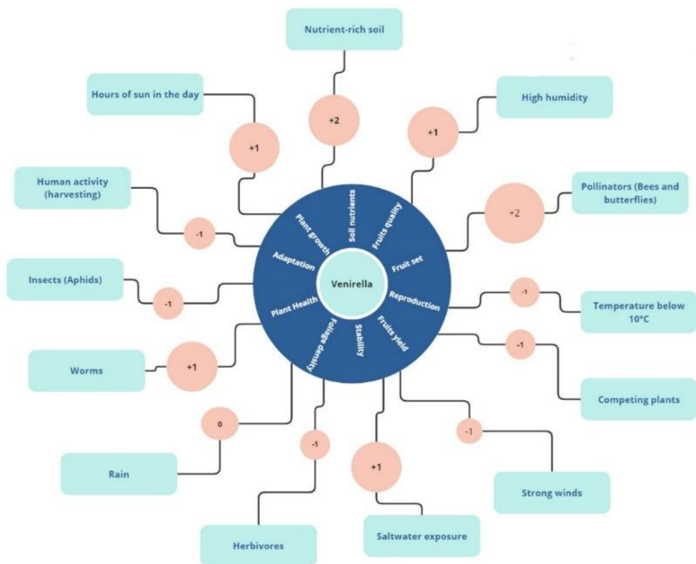

Figure 17. Venirella Common-Sense Connections

PAI Principle 5: Value System

In human societies, personal and social values guide behaviours and decision-making. They define preferable actions and outcomes. Similarly, in the process universe, shared values and larger goals play an important role in the direction and overall development of entities. Moving through their becoming process, entities are encouraged to make decisions based on possibilities that are supported by shared values. All entities are part of a whole and unified organism. As a result, shared values are aligned with the greater good of this organism and ensure working toward the larger goals.[168]

This is how values are laid out in the process of becoming. Entering the Cosmic Cycle, an entity starts with an initial purpose or "subjective aim." This offers aspiration and suggests an

[168] Whitehead, *Process and Reality*, 346.

ideal outcome based on the larger organism.[169] The initial aim defines a set of values and goals by offering an aspiration and an ideal outcome for an entity. For instance, the Venirella plant's ideal purpose could be to procreate and support other life forms. As entities interact with the environment, they face obstacles and need to make choices. Although entities have the freedom to choose between all the possibilities, some of the possibilities present themselves with a "lure." Lures appear as attractive possibilities to direct entities toward making choices that are aligned with shared values and the long-term goals of the whole organism.[170]

[169] Whitehead, *Process and Reality*, 128.

[170] Whitehead, *Process and Reality*, 346; Holmes, "A History of Philosophy | 61 Whitehead's Process Philosophy"; Arthur Holme, "A History of Philosophy | 63 Whitehead's 'Science and Modern World,'" June 16, 2015, https://www.youtube.com/watch?v=x1IwCOx1dlw.

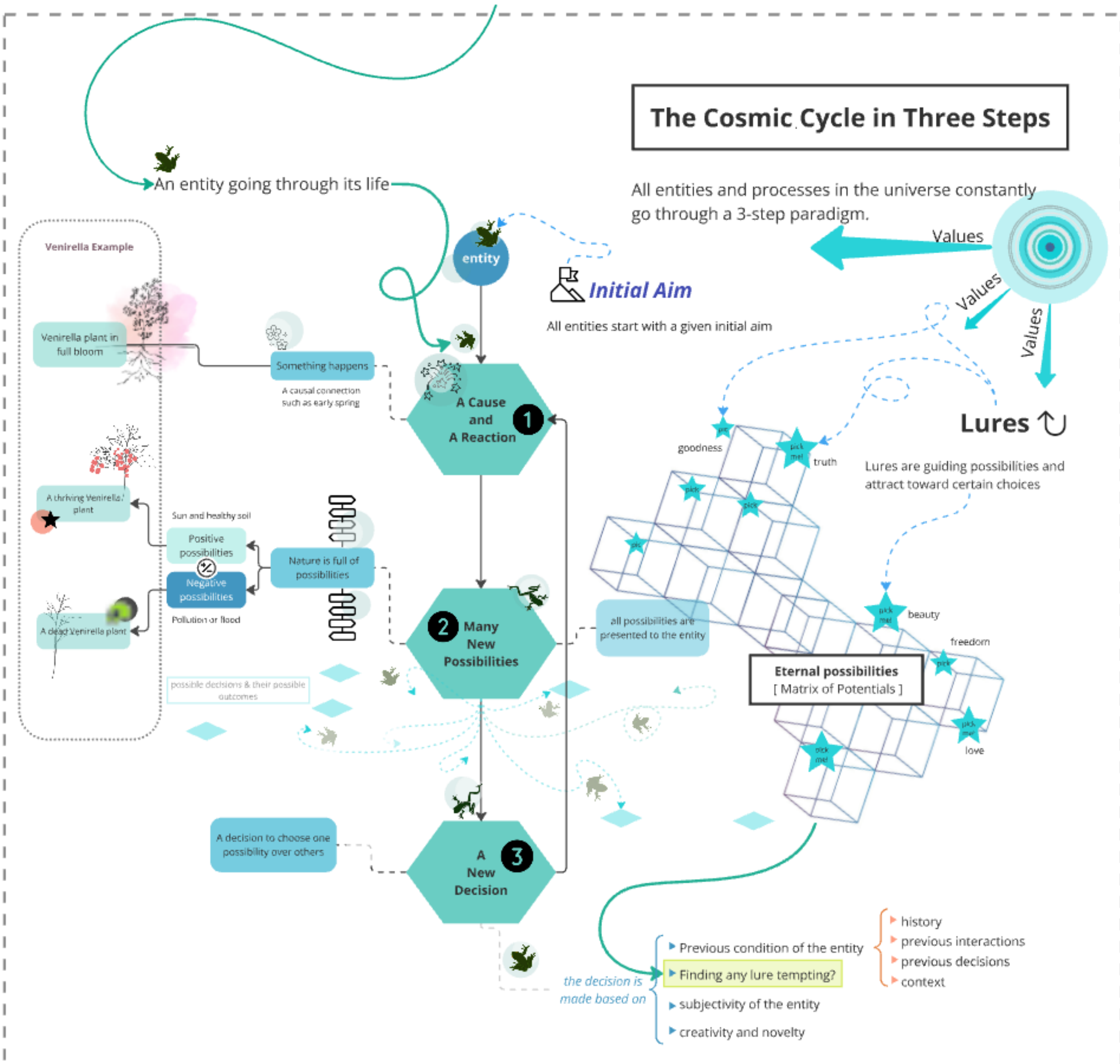

Figure 18. The Cosmic Cycle in Three Steps

To summarize, both long-term goals and values are embedded in every iteration of becoming. Each becoming process is another chance to create, adjust and gently guide the whole organism by fine-tuning the initial aims and lures for actual entities. These values work toward the survival and unity of the larger organism.

AI Design Point: Shared Values

In a PAI framework, values are central to the development and functioning of the system. When designing a PAI, it's essential to establish clear goals and values from the early design stage. A clear map of values and their priorities is a crucial step in a PAI framework. Considering values involves understanding different voices, their needs, and the overall goal of the system. Implementing values could mean including a central memory system to track the overall progress and adding an engine to provide positive and negative feedback to ensure adherence to the long-term goals and values. A value engine monitors the operation and makes sure the system goals are followed. When encountering anomalies, instead of halting the operation and starting afresh, a PAI system works through small changes to improve and move forward.

PAI Principle 6: Prehension System

Prehension

Prehension is a process where an actual entity or apprehending subject receives data from the environment and processes it based on its previous experiences.[171] The act of prehension means combining new information with previous experiences to make decisions. Interacting with the environment, entities accumulate their own subjective experience and use it in their future decision-making. When facing a new situation, eternal objects define all possibilities in a scenario. Relying on their previous experience, entities could prehend these new possibilities negatively, reject them, or positively, accept them. [172]

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[171] Sherburne, *A Key to Whitehead's Process and Reality*, 9.

[172] Whitehead, *Process and Reality*, 49, 343; Sherburne, *A Key to Whitehead's Process and Reality*, 11–12.

Similarly, these values are integrated into the system and offer possibilities when actual entities make decisions and prehend something. When a process interacts with another process or event, out of all the eternal possibilities, only those with positive prehension will be considered for the final decision. This also means each process, depending on its history and subjective experience, can accept only a certain number of prospects. For instance, a spring frost limits the Venirella plant's possibilities later in the summer.

The illustrated map looks at different possibilities in the transformation of a Venirella bush from its beginning in early spring. For Venirella, prehension is about interaction with the environment through factors such as weather, light, water, and other species that can influence the growth and development of the plant.

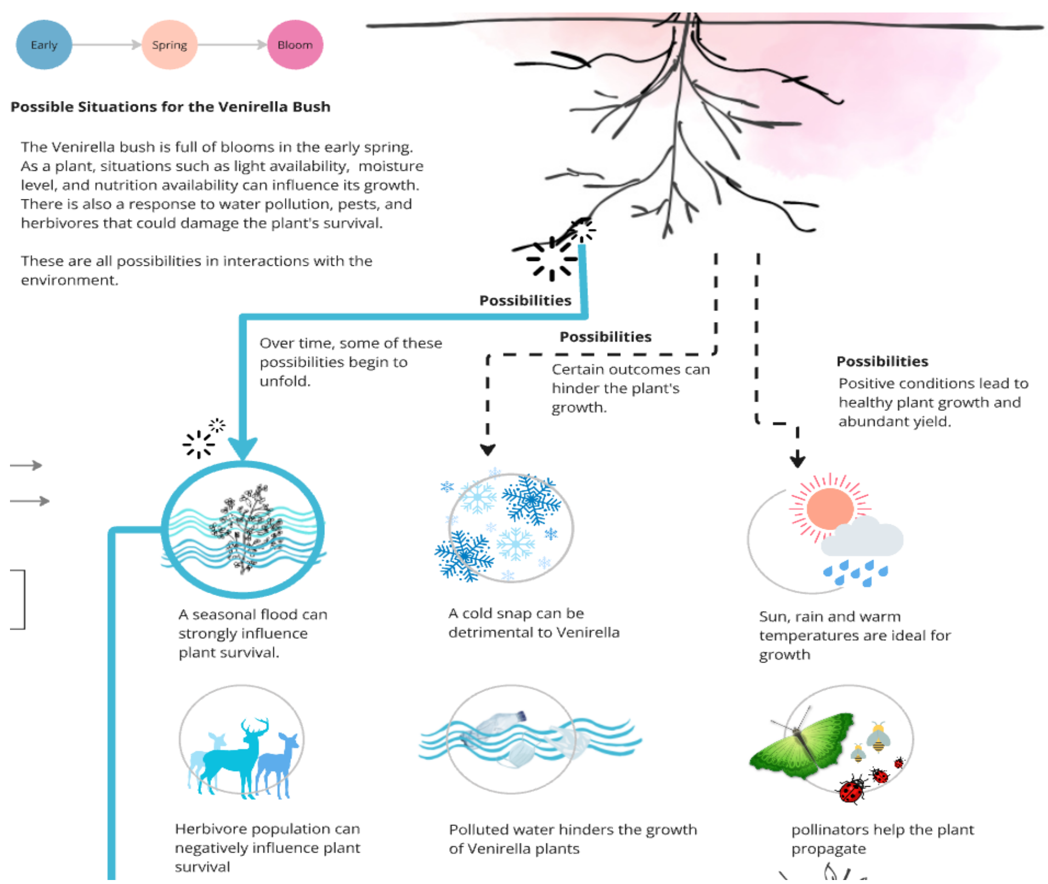

Figure 19. Prehension and Transformation

PAI Design Point: Prehension

In the PAI framework, incorporating the process of prehension makes AI more context-aware. Since prehension is an ongoing process, it also contributes to adaptive learning and shifting AI outcomes, according to environmental feedback and offers a systematic way to include context. Moreover, the context is always tangled with the past and present of an actual entity and will have an immediate effect on its transformation and future possibilities.

For implementation, a prehension system can be built into AI through a prehension engine. A prehension engine could be a combination of a memory system and feedback loops, where data from each interaction influences change in future decisions in AI. The prehension process and value system work side by side and are informed through a feedback process. The prehension engine is a piece of code that activates when new possibilities arise. The prehension engine looks through the possibilities and, depending on the process, proceeds with it or chooses a different path. The following flowchart and pseudocode lay out the internal workings of the prehension engine.

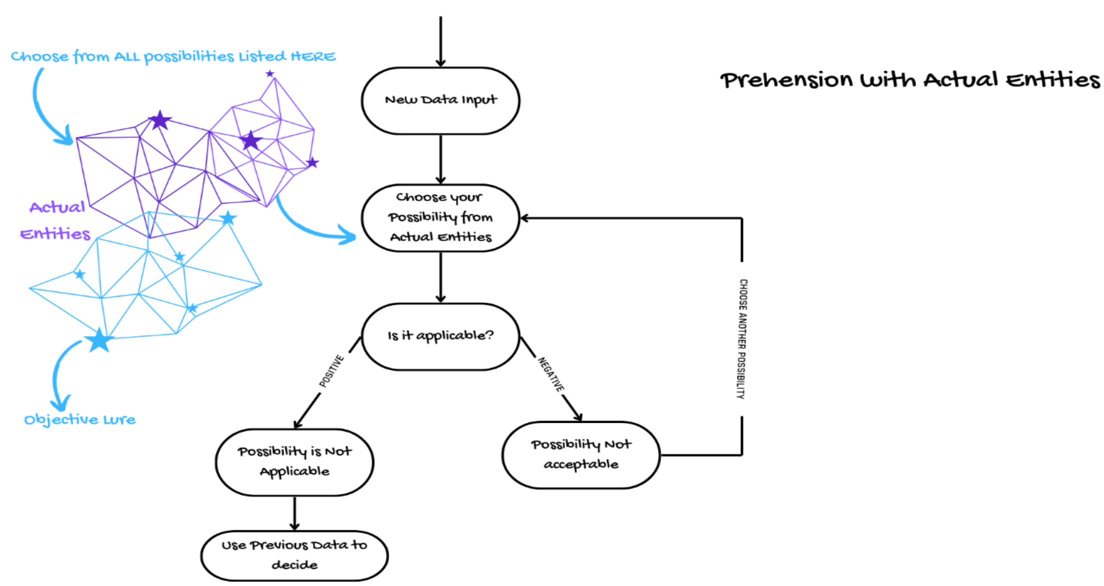

Figure 20. Prehension Algorithm and Pseudocode

```
Input: New Data (Something new happens)
Start Prehension Process
    P1: Receive New Input
    P2: Choose From {Eternal Objects} * {objective lure} here
    P3: IF the Possibility is Applicable here?
              Positive Prehension – You can generate new ideas.
        Else
              Negative prehension – Not Applicable
        GOTO: P2
        End if
    P4: Make a Decision
End prehension Process
```

Co-Creation with AI and Different Forms of Knowledge

In this section, the second PAI map explores the interaction and dynamics between AI and human agents. Here, we explore the role of each party in the creation of knowledge and refinement of the outcomes to reach novelties or breakthroughs. The process universe is an evolutionary organism, and its goal is to make creative advances through iterations.[173] In the process system, creativity is the goal and the "ultimate matter of fact."[174] Thus, each cycle of becoming is an opportunity for creative progression toward novelty and discovering possibilities that were not available in the initial stages. At the core of the PAI framework is a strong focus on interaction and collaboration between humans and AI. This translates into converting human knowledge to AI and working with AI to adjust to these instructions. Because of these collaborations, a new body of knowledge is added to the PAI system based on human thinking and experience. In the following, we examine the nature of this collaboration, the role of creativity and novelty, and the nature of knowledge in a PAI system.

[173] Whitehead, *Process and Reality*, 105.

[174] Whitehead, *Process and Reality*, 21.

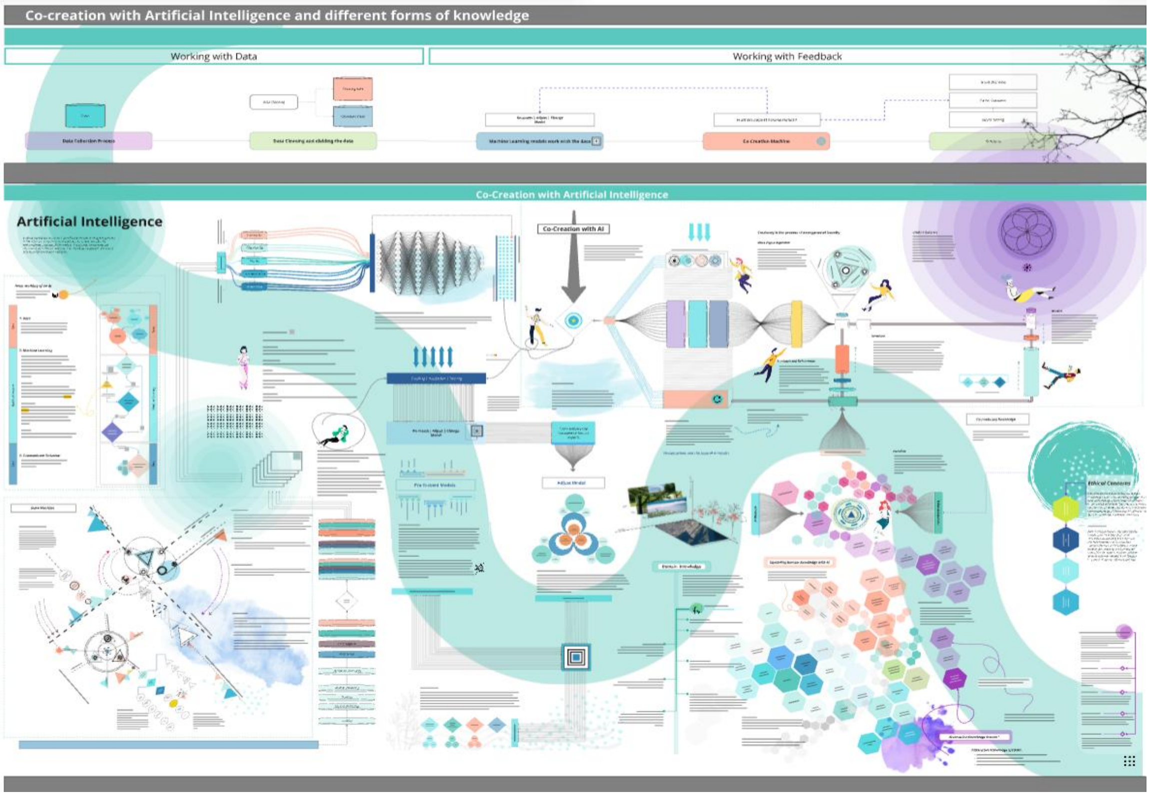

Figure 21. Map II, Co-Creation with AI

Creativity and Co-creation with AI

In the process universe, "creativity is the ultimate behind all forms, inexplicable by forms, and conditioned by its creatures."[175] Consequently, it is considered the main driving force behind the ongoing changes in the cosmos. In the PAI framework, creativity is made possible through the act of prehension. As AI machines and human agents collaborate, they learn from each other and incorporate their previous experiences into future results (prehension). Human agents learn from the efficient analysis of the machine. Similarly, AI adjusts and learns based on human feedback through a continuous conversation or exchange of information. In this collaboration, AI accelerates the research and the creativity process by taking over time-

[175] Whitehead, *Process and Reality*, 20.

consuming tasks and offering more possibilities in a shorter time. The ability to speed up the study through collaboration with AI increases the likelihood of discovering novelties.

In process philosophy, creativity is the act of prehending the surroundings and combining new forms of experience with older ones to create novelty. The act of feeling transforms data from the environment into new subjective experiences, which, in turn, create unique perspectives and lead to innovative responses. When two entities interact, they exchange information and create new insights. This interaction leads to creation through participation and co-creation.

To put it differently, interacting with the environment and other entities through prehension results in the emergence of new patterns or novelties through collaboration. In effect, novelty emerges as actual entities go through the process of prehension and create new possibilities. Here, "creativity introduces novelty". That is to say, "the 'creative advance' is the application of this ultimate principle of creativity to each novel situation to which it originates."[176] Thus, novelty in the process model is not a one-of-a-kind or accidental happening. Rather, novelty comes through a systematic and recurring process of creativity, by combining the previously known with new possibilities.

A PAI system starts with a beginning that is not necessarily ideal for solving different problems. However, the system learns through interactions and feedback from the environment and moves toward novelty. It works in iterations and evaluates the outcomes in each step to avoid larger mistakes and penalties. Similarly, subsequent repetitions will be adjusted by comparing the outcome to the values and goals of the system. Furthermore, these incremental adjustments allow for novelties that could only be reached through a combination of accidental juxtapositions and working toward systemic goals. This co-creation between humans and AI

[176] Whitehead, *Process and Reality*, 21.

creates an entanglement between the two and leads to the co-creation of knowledge that cannot be reached independently.

The dynamic between AI and the human agent in process-oriented AI is similar to Karen Barad's notion of "intra-action." Barad is an American physicist and feminist theorist. In *Universe, Halfway: Quantum Physics and the Entanglement of Matter and Meaning,* Barad introduces the idea of "intra-action" as a special type of interaction between the human and the machine. As opposed to interaction, which involves two separate entities, "intra-action" is about continuous interaction. Applying Barad's concept of "intra-action" to humans and AI results in something like prehension in focusing on exchange and emergence through relations. In both instances, the continuous act of becoming influences both sides of the communication. However, actual entities that guide the interaction don't exist in Barad's "intra-action." Similarly, in Barad's agential realism, intra-acting agencies are ontologically inseparable as opposed to entities in the process that are ontologically separate.[177]

Donna Haraway's "cyborg" introduces another type of entanglement between humans and intelligent machines. "Cyborgs" are a hybrid of humans and machines. Therefore, again, there is a co-creation and collaboration between the machine and the human. However, cyborgs blur the distinction between the machine and human and blend biology and technology to shape a new type of blended identity and agency. By contrast, in PAI co-creation, despite the entanglement between the human and AI in the co-creation of knowledge, the two subjects are fundamentally separate and can only influence one another.[178]

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[177] N. Katherine Hayles, "The Black Hole of Quantum Theory," *NOVEL: A Forum on Fiction* 48, no. 1 (2015): 148–50.

[178] Donna Jeanne Haraway, "A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century," in *Simians, Cyborgs, and Women: The Reinvention of Nature* (Routledge, 1991).

Co-creation of Knowledge

A process universe is an interconnected reality. Accordingly, the PAI framework combines different disciplines to discover novelties that are not possible without multidisciplinary partnerships. The platform facilitates collaboration among different human agents from various fields to create this. As different teams of experts work to create causal maps, and common sense and transfer their domain knowledge to the AI machine, they add their diverse voices to the system.

At this point, AI facilitates communication among experts from different disciplines. This collaborative approach to solving problems requires bringing community members, scientists, public representatives, historians, cultural experts, and artists into the process. Consequently, creating knowledge is a collective process among AI and all other players.

The strength of the PAI system is in its ability to learn and integrate knowledge from different players. This continuous learning allows for the addition of nuances and alternative types of knowledge in decision-making. In this scenario, creating knowledge is a collective process that requires alliances from different fields and backgrounds with different aims to find novel solutions.

A PAI system is a pragmatic model which aims for tangible outcomes. This means that collaboration and adjusting outcomes could be facilitated through codes that work alongside the AI system and could be implemented through various engines to translate relational information into an AI system. One of the consequences of this model is that a PAI system can be trained in diverse environments to adapt to different cultures and ways of life. Collaboration with AI to create relational maps from different perspectives can introduce marginalized voices and local values and traditions into an AI system.

Using the PAI framework provides time to test and improve the knowledge gained through the AI. In Isabelle Stenger's terms, it is a 'slow science' model which works with community members (subjects of the study), scientist-researchers, and AI developers who would each have a say in the outcome. Here, the knowledge is plural and formed through negotiation. It considers different perspectives and modes of knowing, such as through empirical sciences, human experience, and cultural and historical knowledge. As part of this negotiation, there is an ongoing evaluation process to understand if the results are well-founded.[179]

Furthermore, using a feedback model to add knowledge back into the system allows for a mix of intuitive assessment, embodied knowledge, and lived experience to influence the empirical outcome. Giving voices to personal experience and domain experts, personal stories and traditional practices introduce an 'alternative' knowledge system that stands outside empirical knowledge.[180]

Layering direct experience and personal stories into the empirical results introduces possibilities that were not originally considered in the AI design but can become important under different circumstances. This approach gradually introduces lived experiences into the PAI system and adds what Donna Haraway calls 'situated knowledge' into knowledge production.[181] Haraway's situated knowledge requires accepting the partial perspective of scientific facts and taking into account their dependence on contexts such as time, location, social, and cultural

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[179] Isabelle Stengers and Stephen Muecke, *Another Science Is Possible: A Manifesto for Slow Science*, English edition (Polity, 2018), 52–53.

[180] Stengers and Muecke, *Another Science Is Possible*, 9.

[181] Stengers and Muecke, *Another Science Is Possible*, 9.

factors.[182] Integrating such context leads to more transparency and thus accountability in the final results.

Conclusion

To summarize, a process-oriented AI is fundamentally a collaborative approach among human developers, AI machines and human audiences. This collaboration is facilitated through various reworking procedures and feedback loops that inform the core of the AI system about the direction of its progress. This central unit maintains the memory of previous experiences and ensures that the system will stay aligned with its values and long-term goals.

Similarly, implementing a prehension engine provides an opportunity to include context in every step of the process. This could translate into introducing different perspectives and ensuring that diverse viewpoints are included from an early point in the design process. For instance, field experts, policymakers, psychologists, community representatives, and educators could work together to map causal relationships, common sense, and values into the system. This early collaborative effort in the design process could embed relevant voices from the first stages of planning. This could also mean continuous collaboration with experts and those with domain knowledge to assess system outcomes. In the next chapter, we will use SproutCityTO as a case study to expand on the outcome of these principles in a more practical scenario.

[182] Donna Haraway, "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective," *Feminist Studies* 14, no. 3 (1988): 575–99, https://doi.org/10.2307/3178066.

Chapter 5: SproutCityTO Case Study

In the previous chapter, I established the reasoning behind the six PAI principles. In this chapter, I apply these principles to a real-life scenario and explore how they might work in making an AI application. Using the SproutCityTO case study to explore its philosophy and design, I analyze the UI/UX elements, database design, and algorithmic requirements. The goal is to better understand the applicability of PAI principles by using them in a practical scenario.

SproutCityTO App

SproutCityTO is a web application that I envision being created in response to mounting climate challenges and the lack of community engagement I observed in tackling these issues. SproutCityTO brings the natural environment to the attention of the public by offering a platform for community collaboration, personal growth, wellness, and engagement with nature. The app helps people connect with others through mindfulness of nature, science, the local ecology, and by engaging them in volunteer efforts to protect the environment. The goal of SproutCityTO is to connect community members, enhance individual well-being and improve climate consciousness by bringing climate resilience to people on a personal level.

The app uses AI and combines quantitative and qualitative analyses to inform and effectively connect people to their natural environment. It does this by collecting and presenting lived experiences and cultural stories alongside empirical factual information. The SproutCityTO app design builds on a PAI framework to allow for the integration of different voices and uses human and AI collaboration to continuously improve the app in working towards its goals.

Methodology and Case Study

PAI principles offer a unique theoretical framework for working with AI. In this dissertation, I use SproutCityTO as a prototype to offer a more pragmatic way of presenting this framework. To achieve this, I use holistic product design and concept mapping to evaluate the outcome. Here, the concept mapping process allows for stepping outside the limitations of the technology and takes a creative turn to examine how process philosophy can influence AI design on a practical level. The SproutCityTO case study works with PAI principles to combine empirical data with human experience and weaves them both into interactive storytelling. By layering population data with urban natural environmental data, the case study envisions a web platform that facilitates understanding through data and allows for different forms of interaction.

SproutCityTO adapts a "mixed mode of perception" that allows for imagining possibilities in the past, present, and future of an urban landscape.[183] It builds on the premise that data is not objective and requires being integrated with human experience and contextual knowledge in order to interpret results and identify meaning accurately.

A Pressing Challenge: Heating Cities

Cities are the economic engines that support the livelihood of the population and the larger economy. Toronto is a major metropolitan area with an increasing population and a growing demand for housing. It had a growth of +29 ^{km2} in built-up areas between 2010 and 2020, the highest among all major urban centers in Canada.[184] The pressure on the housing

[183] Whitehead, *Process and Reality*, 168.

[184] Statistics Canada Government of Canada, "The Daily — Census of Environment: Measuring Settled Area Expansion, 2010 to 2020," October 27, 2023, https://www150.statcan.gc.ca/n1/daily-quotidien/231027/dq231027c-eng.htm.

market, lack of rental units, population growth, and absence of advanced planning have resulted in many attempts to push development projects deeper into green spaces, even into the protected green belt region.[185]

The rapid growth of cities is a challenging reality in contributing to a warming climate. According to Environment Canada, from 1948 to 2022, the annual average temperature in Canada increased by 1.9°C.[186] Moreover, urban areas like Toronto are up to 3°C on average hotter than nearby rural areas, due to the Urban Heat Island (UHI) effect. The UHI refers to higher city temperatures in overdeveloped urban centers.[187] UHI occurs when building materials such as concrete and asphalt absorb heat from the sun during the day, which prevents them from cooling at night.[188] The combination of new development, rising temperatures, and the additional energy needs of air conditioning to cool down on hot days makes addressing UHI an urgent priority. UHI is negatively correlated with human health; the link between extreme heat events and hospital admissions of older adults is well-documented. For example, research from 114 cities in the US finds a 3% increase in hospital admissions up to eight days after an extreme heat event.[189] The consequences of UHI are magnified when considering the rapid growth of urban centers.

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185 Hannah Jackson and Ryan Rocca, "Toronto Is in a Housing 'Crisis' Leaving Newcomers, Residents in the Lurch | Globalnews.Ca," Global News, 2023, https://globalnews.ca/news/9882577/new-roots-toronto-housing-immigration/; Allison Jones and William Eltherington, "Doug Ford Reverses Plan to Allow Housing Development on Greenbelt Lands | National Post," 2023, https://nationalpost.com/news/politics/d-ends-greenbelt-development.

186 Environment and Climate Change Canada, "Temperature Change in Canada," research, July 10, 2023, https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/temperature-change.html.

187 Health Canada, "Climate Change and Health - Adaptation Bulletin," navigation page, December 17, 2020, https://www.canada.ca/en/health-canada/services/environmental-workplace-health/reports-publications/climate-change-health/climate-change-health-adaptation-bulletin-number-1-november-2009-revised-december-2010-health-canada-2009.html.

188 Health Canada, "Climate Change and Health - Adaptation Bulletin."

189 Carina J. Gronlund et al., "Heat, Heat Waves, and Hospital Admissions among the Elderly in the United States, 1992–2006," *Environmental Health Perspectives* 122, no. 11 (2014): 1187–92, https://doi.org/10.1289/ehp.1206132.

An effective Solution: UGS and Increasing Awareness

An efficient measure for regulating city temperatures is the use of Urban Green Spaces (UGS). UGS lower temperatures and remove CO_2 emissions and other pollutants from the air.[190] However, the growth of cities has presented ongoing challenges to maintaining green spaces within major metropolitan areas. The increase in population and expansion of cities have decreased the "average urban greenness" by turning agricultural lands, wetlands, and forests surrounding big cities into roads and new construction projects.

"Urban greenness" is a measure used by Statistics Canada to assess the health of urban green spaces.[191] From 2019 to 2023, the city of Toronto experienced an 11.3% reduction in its "urban greenness."[192] The loss of urban greenness comes with negative consequences for human health, biodiversity, wildlife habitats, natural water flow, and local climate regulation.[193]

Most efforts to reduce global emissions are targeted toward governing policies and remain outside citizens' grasp. However, grassroots efforts to improve our relationship with UGS can enhance the local climate and be a positive step toward climate change mitigation. Advocating for a stronger bond between humans and nature raises support for UGS. The SproutCityTO app is a citizen-led initiative designed to raise personal and public awareness of the benefits of nature. Its goal is to increase appreciation of the natural environment and ultimately to elevate public support for UGS.

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190 Simon Elias Bibri, "Data-Driven Smart Eco-Cities and Sustainable Integrated Districts: A Best-Evidence Synthesis Approach to an Extensive Literature Review," *European Journal of Futures Research* 9, no. 1 (2021): 16, https://doi.org/10.1186/s40309-021-00181-4.

191 Statistics Canada Government of Canada, "The Daily — Census of Environment: Urban Greenness, 2023," November 15, 2023, https://www150.statcan.gc.ca/n1/daily-quotidien/231115/dq231115c-eng.htm.

192 Statistics Canada Government of Canada, "Urban Greenness, Large Urban Population Centres, Top Five Largest Centres," November 15, 2023, https://www150.statcan.gc.ca/n1/daily-quotidien/231115/t001c-eng.htm.

193 Government of Canada, "The Daily — Census of Environment," October 27, 2023.

Climate Consciousness, Wellness and Green Spaces

Trees and green spaces have a positive impact on the overall well-being of communities. They decrease urban pollution, lower temperatures, and improve the population's well-being.[194] A growing body of evidence highlights the positive effects of UGS on human health, improved mental health and overall well-being.[195] They bring communities together and offer an opportunity for relaxation.[196] Research consistently points to a strong association between tree canopies and health benefits in all categories.

Urban Green Spaces are an important part of the urban ecosystem, since they improve the quality of life and sustain wildlife within the city. UGS refer to city spaces that are covered with vegetation, such as parks, woodlands, wetlands, and natural habitats along the riverbanks and lakes. They can also be green rooftops or permeable driveways. UGS play an important role in promoting urban sustainability.[197] They are also known for their potential role in lowering temperatures and mitigating climate change.[198]

A systematic review of 68 articles and 59 studies on UGS shows that they are associated with lowering allergic symptoms, alleviating respiratory conditions, decreasing cardiovascular

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[194] OAR US EPA, "Heat Island Effect," Collections and Lists, February 28, 2014, https://www.epa.gov/heatislands; Raffaele Lafortezza et al., "Green Infrastructure as a Tool to Support Spatial Planning in European Urban Regions," *iForest - Biogeosciences and Forestry* 6 (March 2013), https://doi.org/10.3832/ifor0723-006; Natural England, "Natural England's Evidence Published in 2013/2014 - EIN001," Natural England - Access to Evidence, accessed June 28, 2024, https://publications.naturalengland.org.uk/publication/5315133639229440.

[195] Jo Barton and Mike Rogerson, "The Importance of Greenspace for Mental Health," *BJPsych International* 14, no. 4 (2017): 79–81, https://doi.org/10.1192/S2056474000002051.

[196] Patrik Grahn and Ulrika K. Stigsdotter, "The Relation between Perceived Sensory Dimensions of Urban Green Space and Stress Restoration," *Landscape and Urban Planning* 94, no. 3 (2010): 264–75, https://doi.org/10.1016/j.landurbplan.2009.10.012.

[197] Ayyoob Sharifi, "Urban Sustainability Assessment: An Overview and Bibliometric Analysis," *Ecological Indicators* 121 (February 2021): 107102, https://doi.org/10.1016/j.ecolind.2020.107102; Jenő Zsolt Farkas et al., "A Systematic Review of Urban Green Space Research over the Last 30 Years: A Bibliometric Analysis," *Heliyon* 9, no. 2 (2023): e13406, https://doi.org/10.1016/j.heliyon.2023.e13406.

[198] Shah Md Atiqul Haq et al., "Public Perceptions of Urban Green Spaces: Convergences and Divergences," *Frontiers in Sustainable Cities* 3 (October 2021), https://doi.org/10.3389/frsc.2021.755313.

problems, and leading to better mental health.[199] Thus, expanding and improving UGS can improve the population's well-being, lower temperatures, and decrease the need for energy in hotter months. Increasing public consciousness towards UGS can be an important step in gathering public support behind existing tree canopies and their expansion.

One of the most effective approaches in mitigating the negative consequences of the urban island effect is to increase vegetation.[200] UGS not only contribute to cooling the city temperature, but also contribute to population well-being by filtering noise, reducing air pollution and improving air quality. They also enrich the quality of life and sustain wildlife within the city. Green spaces have a direct impact on local temperatures, control water flow, and provide habitat for insects, birds, and other wildlife. One target of the United Nations' 2030 goals in Sustainable Development is "providing universal access to safe, inclusive and accessible, green and public spaces."[201] However, the need for housing and ignorance about the role of green spaces in mitigating local and global climate change lead to a lack of public support.

Despite rising global temperatures and growing urban populations, which create an urgent need for new UGS, public support for maintaining and growing green spaces has dwindled.[202] A survey of 66 global articles on the challenges of implementing UGS links socio-

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[199] Phi-Yen Nguyen et al., "Green Space Quality and Health: A Systematic Review," *International Journal of Environmental Research and Public Health* 18, no. 21 (2021): 11028, https://doi.org/10.3390/ijerph182111028.

[200] Yasuyo Makido et al., "Nature-Based Designs to Mitigate Urban Heat: The Efficacy of Green Infrastructure Treatments in Portland, Oregon," *Atmosphere* 10, no. 5 (2019): 5, https://doi.org/10.3390/atmos10050282; Yansu Qi et al., "A Case Study of the Relationship Between Vegetation Coverage and Urban Heat Island in a Coastal City by Applying Digital Twins," *Frontiers in Plant Science* 13 (April 2022), https://doi.org/10.3389/fpls.2022.861768.

[201] "Sustainable Development Goals (SDGs) and Disability | Division for Inclusive Social Development (DISD)," 2024, https://social.desa.un.org/issues/disability/sustainable-development-goals-sdgs-and-disability; Nguyen et al., "Green Space Quality and Health."

[202] Government of Canada, "The Daily — Census of Environment," October 27, 2023.

demographic, economic, and cultural factors to the lack of acceptance for green spaces.[203] This could also point to a lack of education and/or awareness about the beneficial effects of UGS on communities.

The philosophy behind SproutCityTO is that raising awareness about the role of UGS leads to deeper personal engagement with nature in cities. Creating this personal connection will increase stewardship of green spaces and rally public support when choosing between green spaces and development projects, in the face of rampant growth and an insatiable desire to generate profits, on the part of developers.

SproutCityTO App: Goals and Objectives

The philosophy behind SproutCityTO is that each community member plays an important role in solving the problem of warming cities. It translates larger climate challenges into something personal and relatable. Creating deeper connections with nature will raise public support for expanding and maintaining green spaces, leading to higher appreciation and thus increased stewardship towards them. Most people feel the urgency of the ecological crisis, yet they might feel too powerless to consider how their personal choices can influence the larger climate issues. Faced with melting ice caps and unpredictable weather patterns, an individual's efforts might seem futile and pointless. Moreover, living in temperature-regulated buildings and communicating through fibre optic cables renders the idea of soil, water, trees, and nearby wildlife abstract. Yet, maintaining water, soil, and biodiversity is essential to public health, environmental sustainability and regulating the global climate.

[203] Atiqul Haq et al., "Public Perceptions of Urban Green Spaces."

SproutCityTO is an AI-driven project that connects people with the surrounding nature to preserve and nurture biodiversity and take steps to protect it. It is an interactive web application that emerged as a response to the lack of public attention to the role of nature and rising temperatures in Toronto. This app gives information about UGS and promotes discussion and participation in nature-related activities such as planting trees, park clean up, and learning about the local ecology, history of the land and its ecological features. This is achieved in two ways: first, the app offers AI-generated insights about the impact of UGS on the well-being of neighbourhoods. It also uses data visualization and storytelling to educate and inform the public about their role. Second, the app creates a social network around green spaces and brings nature to the forefront of public attention.

SproutCityTO connects people to their cities by connecting their homes and communities to the bigger ecological changes in their environment. The goal is to project an image of interconnected ecology to public consciousness; engage people with the data and highlight the tangible role of nature in their well-being. In this sense, the app is a platform for community members to educate themselves, engage with others and collaborate in creating various urban greening projects in their neighbourhoods.

This chapter offers a blueprint for building the SproutCityTO app based on PAI principles. The outcome of this chapter could serve as the starting point for developing the SproutCityTO project in the future.

SproutCityTO Impact and Potential

SproutCityTO is a citizen initiative project that tackles climate change from a relational angle. It is built on the premise that strengthening the relationship between humans and nature will deepen human appreciation for nature. This can mobilize public support to maintain UGS and take part in their development and preservation.

A Place to Learn about the Local Environment

SproutCityTO offers a platform to observe biodiversity and allows people to record and report their encounters with wildlife and plant species. Citizens can upload photos, sounds and descriptions of their encounters and discuss them with others. Recording such observations invites people to be attentive to nature and their local UGS. It also helps the SproutCityTO app gather data and assess the biodiversity and health of UGS. Similarly, the app offers opportunities to learn about the land, its history, its ecological features, and its native plants and wildlife.

A Place to Learn About the Effect of UGS

SproutCityTO aggregates and visualizes statistical information about the temperature, air quality, community well-being, and the state of UGS in neighbourhoods. It uses storytelling to engage its users with climate data, demographic data, health data, and measures of well-being. It also highlights the impact of climate change on local ecology and informs about the immediate and long-term effects of green canopies. By bringing these data together, the app shows how UGS impact a population's well-being. The platform can also help researchers and policymakers learn about the immediate effects of UGS on the city.

A Place to Engage with the Community

SproutCityTO offers a social network based on UGS to connect people with green space and help create new social connections through birdwatching, nature observation, nature walks, meditation in nature, and related workshops and cultural activities. Moreover, SproutCityTO is a place for residents to share their stories and memories about nature or UGS. The app encourages users to post pictures and stories about UGSs, discuss their encounters with wildlife, plant species or ask questions about them.

A Place to Find Resources

As a social network, the app has the potential to connect government bodies and NGOs to offer services to make a greener city. This could include providing low-cost saplings of native trees and shrubs or offering low-cost monitors for measuring air quality, etc. Also, it can offer a platform for municipalities to propose nature-related activities and invite experts and artists to engage the public with the natural environment.

A Place for Citizen Scientists

SproutCityTO is a citizen scientist initiative project. It encourages participation and observation in spotting wildlife, identifying invasive pests or plant species, and submitting reports on local air quality and temperature. It persuades users to participate in data collection about parks by recording their observations or leaving their feedback, reviews and discussions about UGS. The AI component of this app uses this data and users' feelings about these experiences to adapt and change its approach accordingly.

A Place for Personal Stories

SproutCityTO offers a place for users to post their experiences in UGS. These could be images, poems, or personal stories and memories. Encouraging personal storytelling enables understanding users' sentiments, expectations and values elicited by UGS. This data can be assessed through analysis to understand and promote activities that encourage a deeper connection with nature.

The AI Advantage

An AI approach helps us to measure the trends and relationships among changing cities, rising temperatures, and population well-being. At the same time, it allows the app to bring information about tree canopies alongside demographic and social well-being data to understand their relationality. Ideally, AI will combine environmental statistics with social and economic records to provide a more holistic image of the impact of UGS. Similarly, relying on satellite imagery, citizen scientist information, and public conversations, the AI system can identify the association between different activities and the overall health and well-being of the UGS and the population that uses them. In the long term, this leads to adjusting and promoting events that have the most positive impact.

SproutCityTO Big Picture Design

SproutCityTO combines AI-generated quantitative analysis with personal stories to present a more accurate image of the city's UGS. The app uses data from the Toronto city website for its quantitative analysis. Much of this process is presented in the supplemented illustration maps.

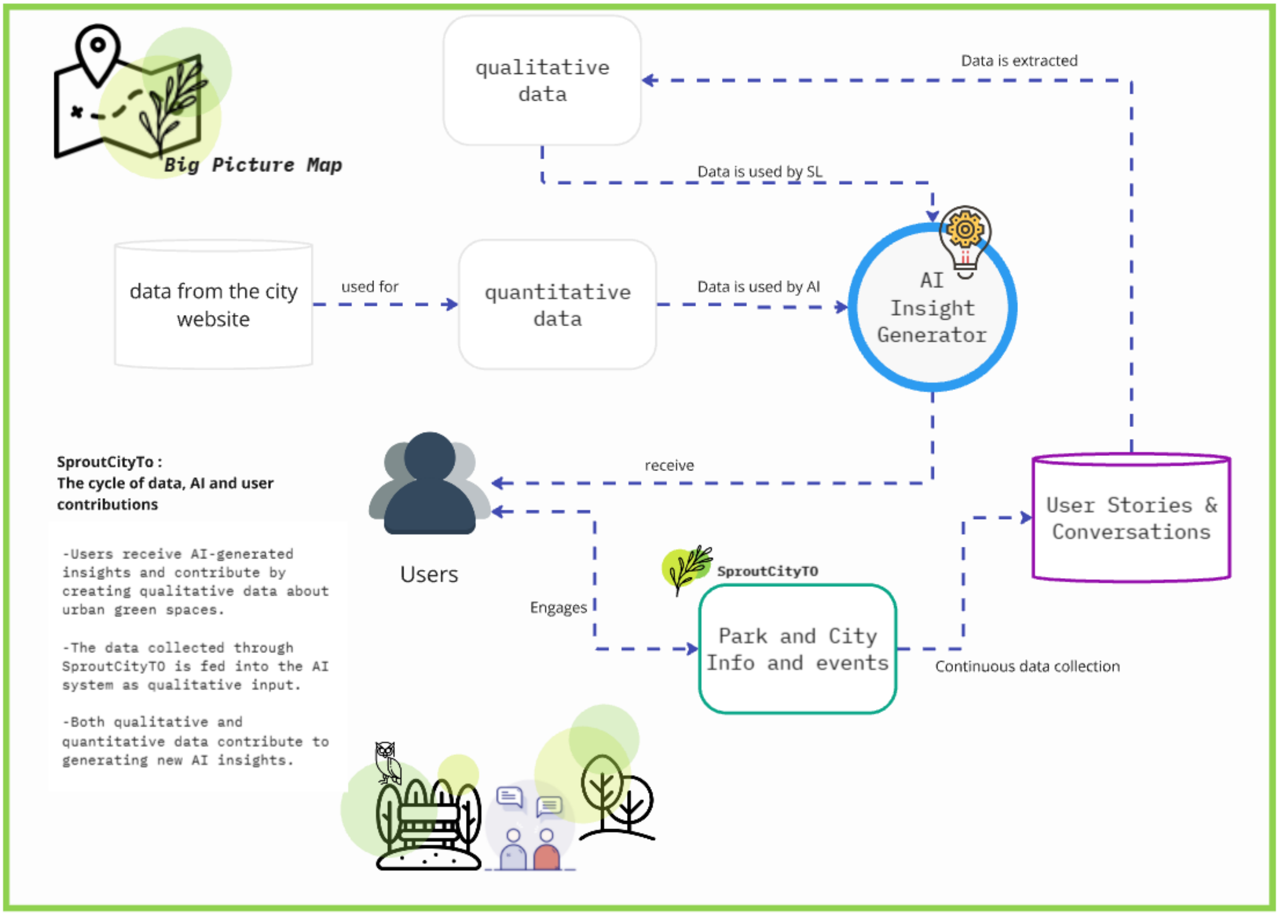

Figure 22. Big Picture Map of SproutCityTO

In SproutCityTO, users contribute by sharing observations about nature, their stories and their participation in local activities. These interactions introduce new data about the park, natural habitats and opinions about these places. Similarly, users' responses are assessed through sentiment analysis to understand the impact of different events and programs. This information is gradually integrated into the system to change its behaviour by promoting activities that offer the most benefits.

Overall Design and Sitemap

SproutCityTO is designed with two directions in mind. Each one offers a different approach to communicating with the app users. The first route, AI Insight, is focused on user education using data stories and analytics about the city and its demographics. This set of reports uses information from the city data to generate reports and lay out how UGS quality is related to population well-being. They also show how changes in green spaces influence neighbourhoods over the years. These reports are generated and updated as new data becomes available.

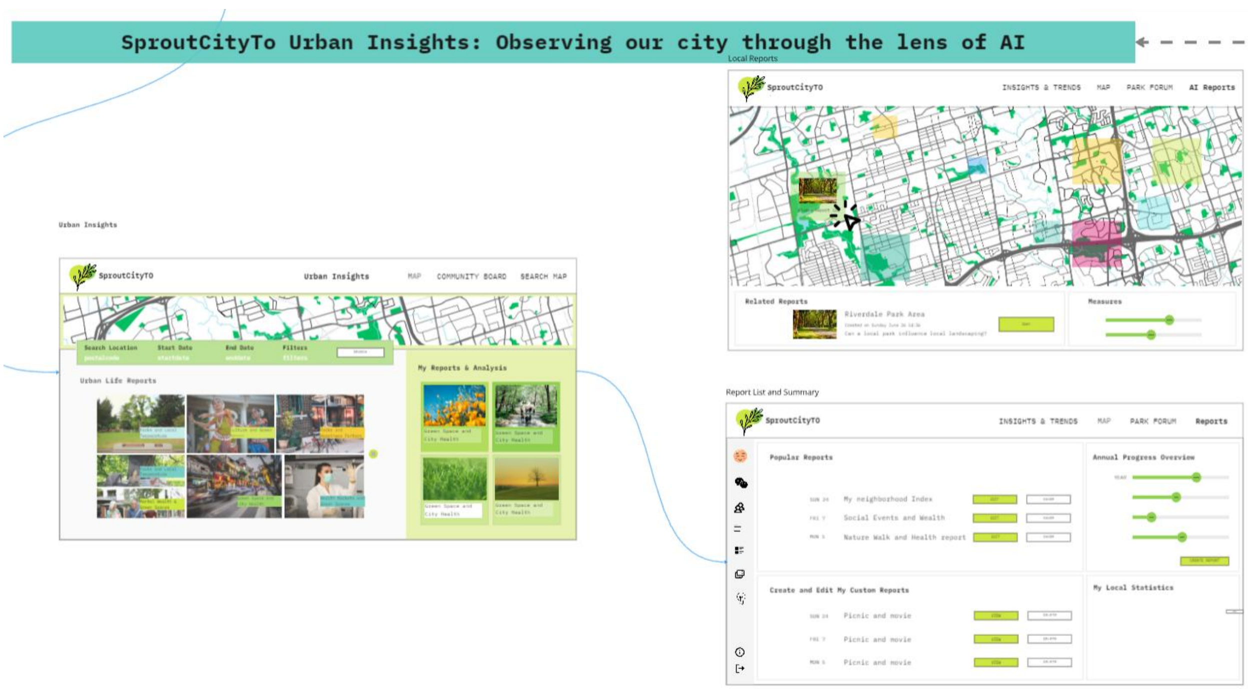

Figure 23. SproutCityTO AI Insight Overview

The second route in SproutCityTO offers a social networking platform around nature to connect people to others, their geography and to local green spaces.

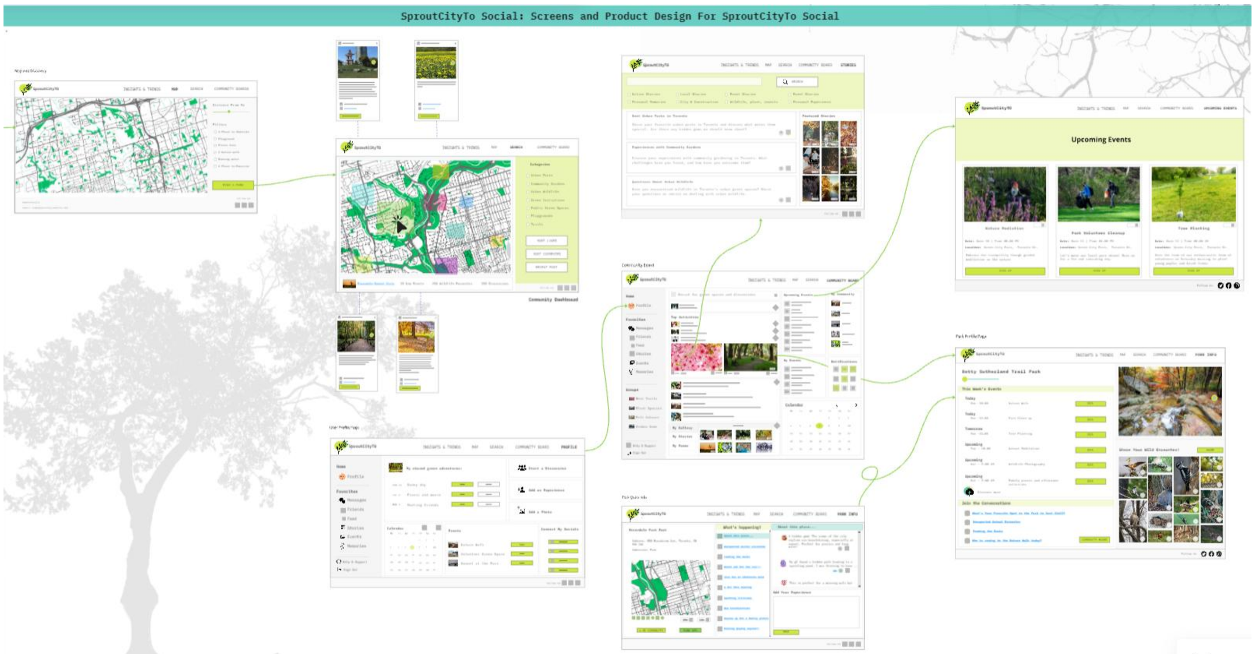

Figure 24. SproutCityTO Social Connections Overview

A Co-creation with AI

SproutCityTO is a collaboration between humans and AI to strengthen their relationship with their environment. The humans in this interaction bring domain knowledge, data about nature, and field expertise, and the AI offers efficiency in analytical reasoning and finding patterns. What is important here is that both the machine and the human engage and work through an iterative process to learn and evolve. Here, the PAI framework ensures that voices from different perspectives and backgrounds are included in AI decision-making.

Design UI/UX for User Engagement

A big part of SproutCityTO is delivered through its interactive and participatory nature. Here, the app's user interface and user interactions (UX/UI) allow users to engage with data trends and reports about their city. Designing UI means considering interactions, access to menus, accessibility and collaboration throughout the project. In the SproutCityTO design, different screens facilitate access to various features. Through its interface, the app offers insights driven by AI and a social network. In the following section, we dig deeper into the UI features and examine their underlying technical elements.

User Interface and Interactions

One of the aspects of this project is to engage community members by incorporating their personal stories and memories associated with different locations and times in urban green spaces. Users can create a profile and use their home screen to connect with others, find their favourite activities, set notifications for their interests and receive calendar reminders. They can quickly access upcoming events in their area. Users can also participate in forums, and add their observations, photos, poems and stories.

The following screen displays the user's home screen and shows how users access their favourite activities and community events. The supplemental Map III offers a zoomable version of the page.

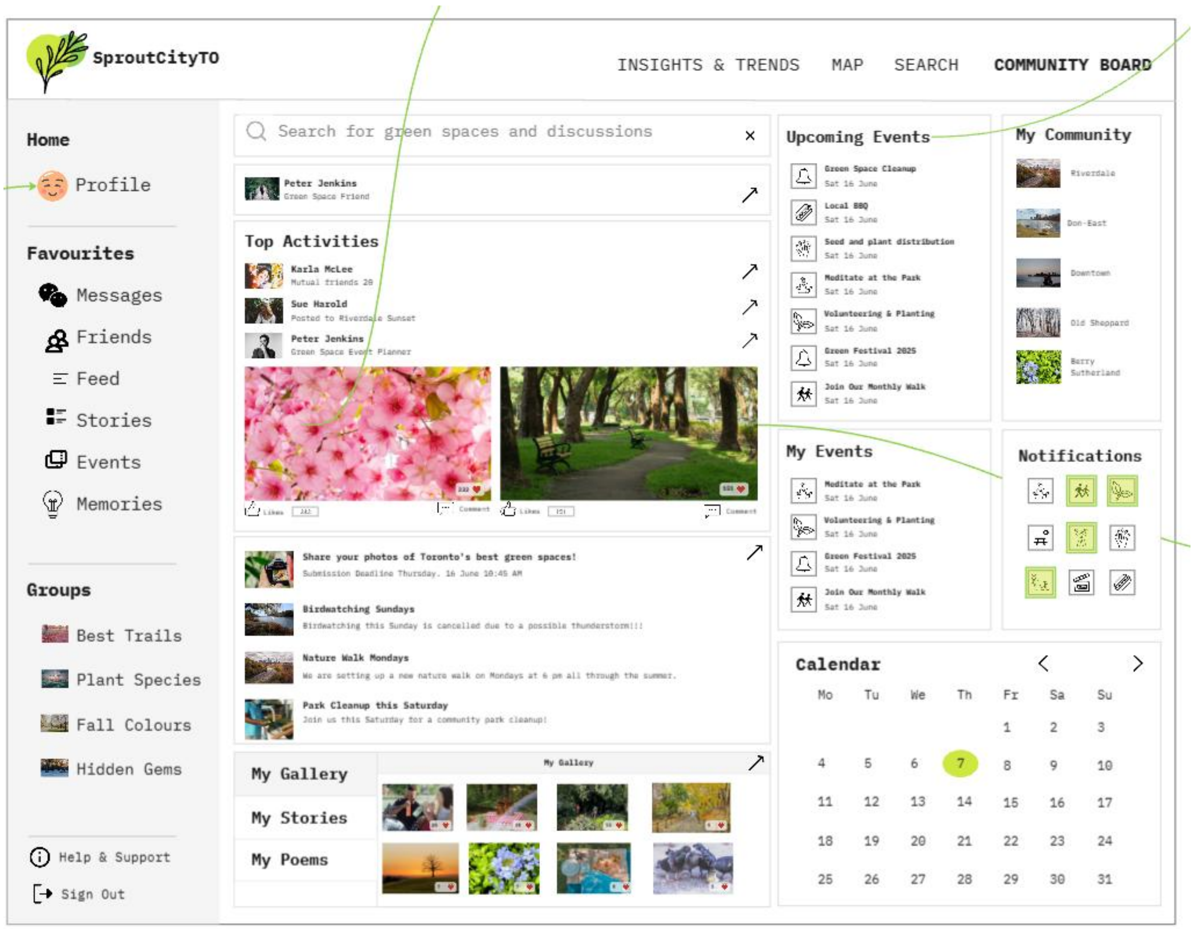

Figure 25. SproutCityTO User's Home Screen

Colours and Design Strategy

SproutCityTO UI offers a modern look in its interface design. This is created through clean lines and a minimalist style. Similarly, the menus and buttons are designed for simplicity and ease of access. Yellow-green and dark-green are primary accent colours, which reflect the nature-focused aspect of the application. The following screen of SproutCityTO represents the visual style and use of colours on the home screen of the web application.

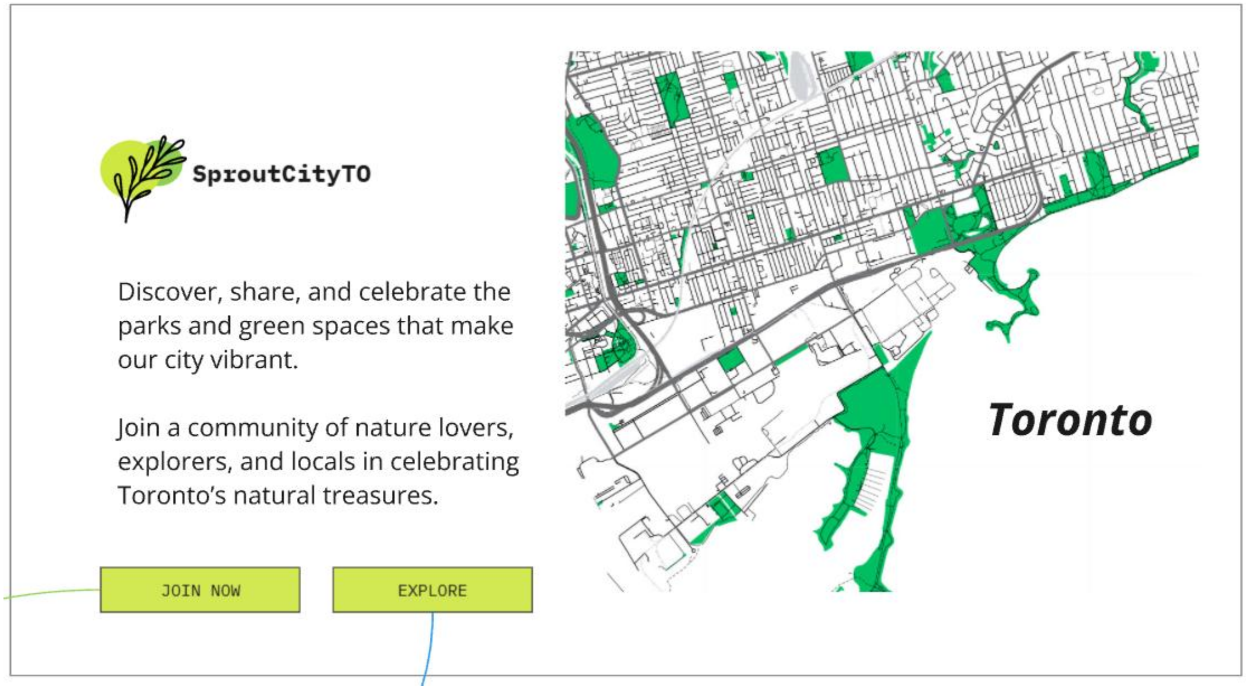

Figure 26. Colour Design for SproutCityTO

Menus

Menus across the top provide easy access to different functionalities and features, such as various reports, social interaction, and posts.

Accessibility and Privacy

Considering the diversity of the population, accessibility is an important element in the design of SproutCityTO to facilitate participation at different levels of ability. This means meeting WCAG standards to offer accessibility and ease of use.[204] These standards produce a clean design, clear fonts, colour contrast and extra features for voice accessibility to reach community members with a wide range of physical abilities. Considering the diverse

[204] Web Content Accessibility Guidelines (WCAG) standard for making content more accessible.

communities in the Toronto area, an option to support multilingual features is essential to reach an even wider range of users. Privacy and transparency also play an important role in the design. Moreover, transparency clearly defines how the users' data is stored and used. Since SproutCityTO tracks user data and feedback to improve its decision-making, it ensures personal privacy by providing clear descriptions of data usage and presents an opportunity for opting out.

In the following sections, I explore the SproutCityTO app through the lens of PAI principles and dig deeper into different aspects of its design.

Implementing PAI Principles

Principle 1 – Data is Relational

The first PAI principle is about interconnectedness and relationality. In process ontology, understanding reality means recognizing the complexity and multiplicity of perspectives. This means that data collection is not a one-sided transaction. Instead, in the process model, data is always exchanged; the observer and the observed are equally present and worthy of consideration. To accomplish this, the design of SproutCityTO starts by identifying all the elements that play a role in the system. These could be geographical elements, such as lakes or shrubs, or more human elements, such as traffic and air pollution. The outcome of this process guides the data collection and the type of data that should be included in the app.

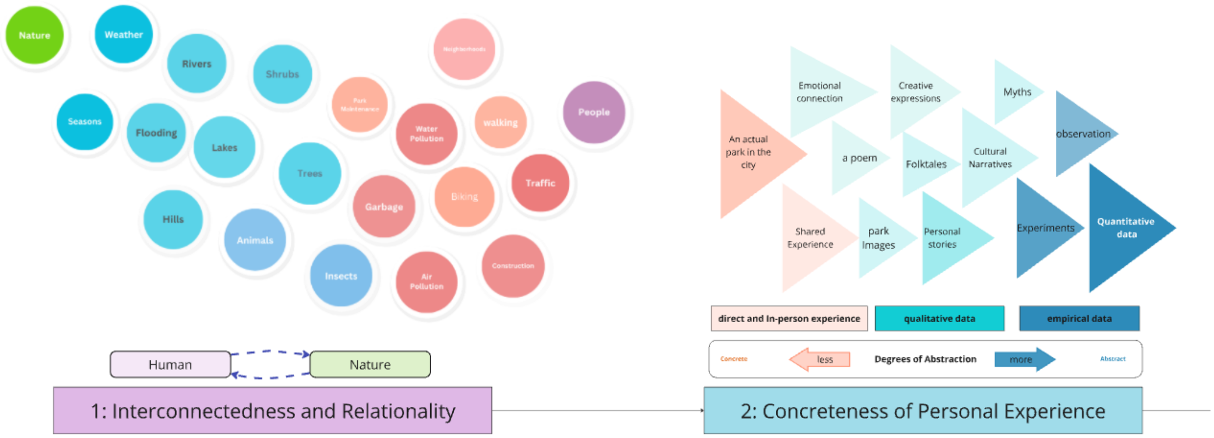

Figure 27. Interconnectedness and Relationality

Mapping the connections around UGS narrows the type of information or datasets that are needed in the app design. Next, we examine the source and the nature of these datasets.

Datasets

To analyze the role of UGS in city life, information about the infrastructure and citizen life quality in general is the two most important priorities. What follows is a list of the data sources considered for SproutCityTO:

Geospatial data: Geospatial data marks the location of city parks and other ecological features. This information also includes data about city parks, gardens, forests, wetlands and other natural habitats. Topological mapping data about the city provided by the Toronto Open Data Catalogue (Toronto ODC) provides a great starting point. In addition, the *Parks and Recreation Facilities* dataset and the *Green Spaces* dataset provide information on this geospatial information.[205]

[205] *Open Data Catalogue*, 2024, https://open.toronto.ca/catalogue/.

Health Data: Toronto ODC, the *Wellbeing Toronto – Health* dataset includes data about various health metrics such as cancer screening data, Public Health Dine Safe inspection results, and fertility and mortality rates.[206]

Economic Data: The *Toronto Economic Bulletin* dataset provides monthly snapshots of the regional economy. This data covers employment rates and household income and provides a good measure of financial well-being.[207]

Education data: *Wellbeing Toronto – Education* includes the grade 9 graduation rate, university and library attendance. This data covers the dropout rate and literacy records in different areas of the city.[208]

Environmental Data: Air quality, including pollutants and carcinogenic scores in various city areas, provides an important layer to present a more complete picture of the city regions. *Wellbeing Toronto – Environment*, *Street Tree Data, Forest and Land Cover* from Toronto ODC provides information about the environment across the 140 neighbourhoods within Toronto. This data covers information on green spaces, green rebate programs, city green retrofits, pollutant and carcinogenic scores, and the city's tree canopy coverage.[209]

Demographic Data: *Wellbeing Toronto – The Demographics* dataset from Toronto ODC includes information about the demographics of the 140 neighbourhoods in Toronto and will continue to provide such information for this purpose. The demographic data includes age, gender, and ethnicity from different areas.

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[206] *Open Data Catalogue*.

[207] *Open Data Catalogue*.

[208] *Open Data Catalogue*.

[209] *Open Data Catalogue*.

Maps and Google Earth Images: Google Earth provides all the images and maps needed for this project. This includes maps of roads, aerial pictures of neighbourhoods and green canopies.[210] Reviewing available data sources brings us to the next step in connecting these datasets and reflecting their relationality. In the following, we consider a data model that reflects the relational nature of these datasets and offers an interconnected approach to the data structure.

Data Model

The raw data sources for SproutCityTO listed earlier are offered in tabular format in Excel or CSV, where rows display the values based on the categories in columns. This is the default format from most statistical sources. Here is an example of data from the WellbeingToronto dataset.[211] As shown in the following snapshot, in this data, the first column is dedicated to neighbourhoods, and the following columns display the variables related to each area accordingly. Similarly, the subsequent rows display values for different regions.

Indicator Values By Neighbourhood

Export To Excel | Export To CSV | Display: Raw Values

NEIGHBOURHOOD	#	COMBINED INDICATORS	TOTAL AREA	TOTAL POPULATION	POP - MALES	POP 0 - 4 YEARS	POP 5 -
West Humber-Clairville	1	N/A	30.1	33,312.0	16,625.0	1,540.0	
Mount Olive-Silverstone-Jamestown	2	N/A	4.6	32,954.0	16,070.0	2,190.0	
Thistletown-Beaumond Heights	3	N/A	3.4	10,360.0	5,055.0	540.0	
Rexdale-Kipling	4	N/A	2.5	10,529.0	5,130.0	560.0	
Elms-Old Rexdale	5	N/A	2.9	9,456.0	4,520.0	540.0	
Kingsview Village-The Westway	6	N/A	5.1	22,000.0	10,575.0	1,425.0	
Willowridge-Martingrove-Richview	7	N/A	5.5	22,156.0	10,635.0	1,175.0	
Humber Heights-Westmount	8	N/A	2.8	10,948.0	4,895.0	440.0	
Edenbridge-Humber Valley	9	N/A	5.5	15,535.0	7,305.0	565.0	
Princess-Rosethorn	10	N/A	5.2	11,051.0	5,430.0	450.0	
Eringate-Centennial-West Deane	11	N/A	8.6	18,588.0	8,915.0	780.0	
Markland Wood	12	N/A	2.9	10,554.0	4,920.0	350.0	
Etobicoke West Mall	13	N/A	1.7	11,848.0	5,630.0	570.0	
Islington-City Centre West	14	N/A	16.4	43,965.0	20,950.0	2,225.0	
Kingsway South	15	N/A	2.6	9,271.0	4,340.0	430.0	
Stonegate-Queensway	16	N/A	7.9	25,051.0	12,255.0	1,385.0	
Mimico	17	N/A	6.9	33,964.0	16,525.0	1,475.0	

When using health indicator data, please read the following notes.
Values in files exported from Wellbeing Toronto will be more precise (to 2 decimal places rather than 1), which may change some neighbourhood rankings.

Figure 28. Preview of the WellbeingToronto Dataset

[210] "Google Earth," accessed July 12, 2024, https://earth.google.com/web/.

[211] "Wellbeing Toronto," accessed July 7, 2024, https://map.toronto.ca/wellbeing/.

Based on the above datasets, there is one tabular data structure or Table for each category of information. For example, one table for demographics, one for well-being, etc. Following this organization, these separate tables would be connected to other tables through unique fields or IDs, such as postal codes. This data structure splits information based on observation of categories and is far from a relational model. Since PAI is built on relational data, this data could ideally be collected with relationality in mind or, if that is not possible, by converting the data into a relational model, such as a graph database.

Connected Data

Although static data models are the standard in AI and machine learning, there is a growing movement toward graph data models. Unlike traditional data models, graph databases are focused on relationships and connections between data points. One of the key instruments in pushing this shift is the need for real-time recommendation systems. Graph data models organize data based on nodes and edges and can be queried like other non-graph data structures. The data management system used in this chapter is Neo4j, which describes itself as the "early graph pioneers" in database management.[212]

In these data models, each node holds all its information and is connected through edges to all its related nodes. Similarly, there is a query language that traces the graphs. For instance, Neo4j offers Cypher as its language to query the graphs. However, using graphs and nodes requires asking different questions while collecting data. For instance, instead of asking what the categories of data in this database are, we need to ask who the entities or players are. The next

[212] "Graph Database Use Cases," Graph Database & Analytics, accessed July 8, 2024, https://neo4j.com/use-cases/.

step after identifying entities is to define their connections. Here is an example of applying this to a section of SproutCityTO data.

[Node] RELATION [Node]

```
Person HAS Education                          Stories HAVE Location
Person HAS Wellbeing                          Stories INCLUDE MediaFiles
Person PARTICIPATE_IN NatureEvents            Location HAS NatureEvents
Person LIVES_IN Location                      Location HAVE UGSs
Person KNOWS Stories                          UGSs INFLUENCES Wellbeing
Person MAKES Posts                            UGSs INFLUENCES AirQuality
```

Here is the display of the same relationships in graphical representation, where nodes or entities are related through edges or their relationships. A similar strategy could be applied to all elements in the system.

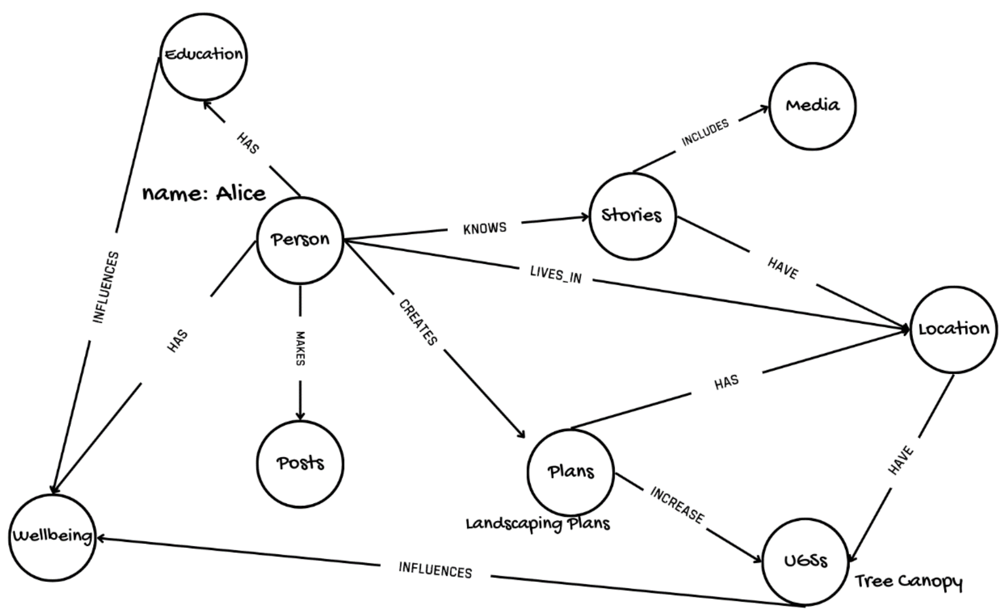

Figure 29. Node Graph of a Section of SproutCityTO

Each node in this graph can have a data structure that holds its information. Here are a few examples: Location node identifies physical locations with their name, elevation, longitude, and latitude. The following code represents the Location node. Here, Cypher language is used to offer the schematics.

Location Node

```
CREATE (l:Location {
        id: "ObjectId('…')",
        name: "North Bridlewood Park",
        type: "Park",
        Address: "11 Adencliff Rd #1M8, Scarborough, ON M1W 1M9",
        Coordinates: "43.7911° N, 79.3194° W"
        description: "Tranquil place, large field of dandelions in the 
summer.",
        created_at: datetime("2023-01-01T00:00:00"),
        metadata: "{'info': 'More details about the place'}"
});
                                                                    Cypher
```

Posts Node

```
CREATE (ps:Posts {
        id: "ObjectId('…')",
        content: "Perfect place for a morning walk.",
        author: "KerbySouthW",
        created_at: datetime("2023-01-01T12:00:00")
});
                                                                    Cypher
```

Stories Node

```
CREATE (s:Stories {
        id: "ObjectId('…')",
        text: "I take morning walks here every day. There is this black cat 
that shows up on my path to say hi. Seems like a wild one and is missing one 
ear 😊",
        media_file: "morningwalk-blackcat.png",
        created_at: datetime("2023-02-02T10:00:00")
});
                                                                    Cypher
```

User Interface

The AI Insight section in SproutCityTO uses the graph data structure to run its data analytics. This is where data and AI statistical analysis are brought together. This section seeks to find patterns in the intersection of the relationalities. AI Insight uses information about air quality, temperature, demographics and the distribution of green canopies across the region. For instance, the AI Insight section seeks to find associations between the size of the tree canopy and UGS and the number of hospital visits, education records, or income levels. The goal is to find correlations between UGS and different well-being and geographical factors. The results are open to public debate and community notes for feedback, discussions and personal opinions. Similarly, users can track and follow their regional reports to stay informed about the changes.

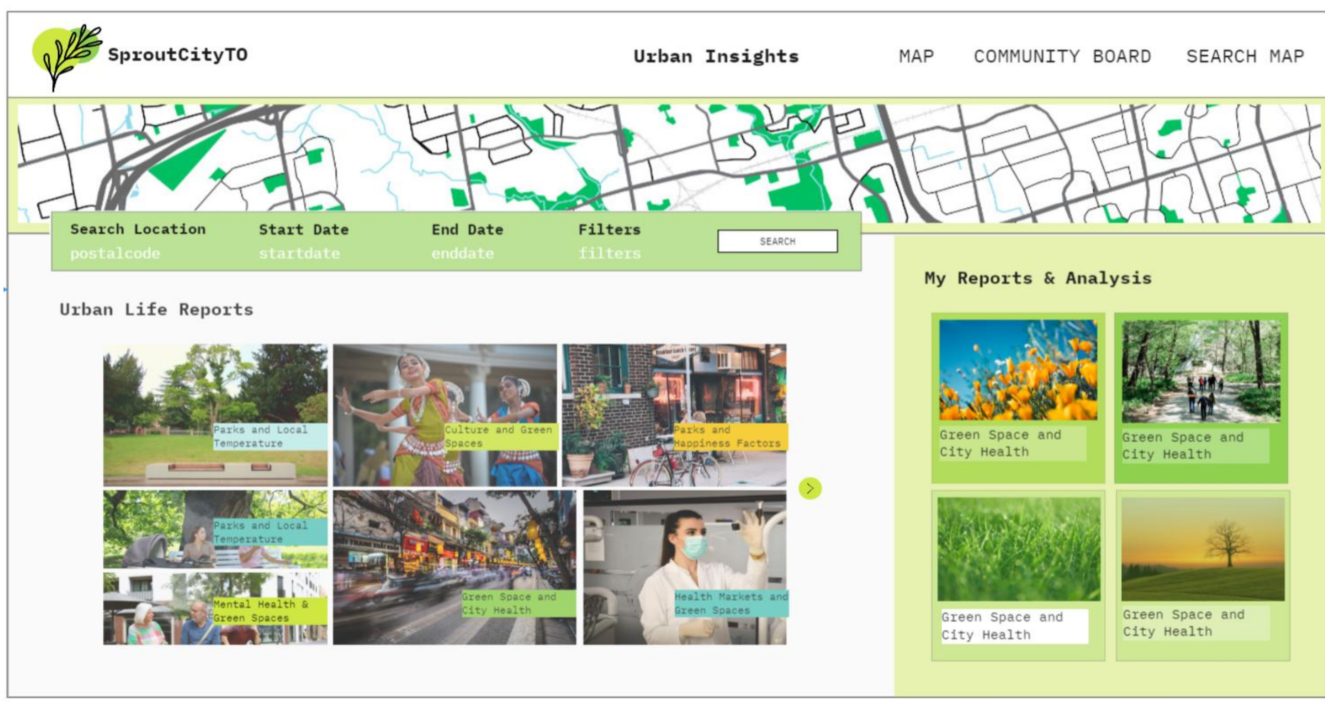

Figure 30. AI Insight Home Screen

Principle 2 – Concrete Data

In process ontology, abstract data refers to quantitative or qualitative data representing names, locations, measures, etc. This is what Whitehead calls Cartesian data, or data that lacks context and direct connection to its source. Most data in the context of AI datasets is within the abstract realm. These could be numbers and values that are often represented in tables. Applying the second principle means layering abstract data with contextual information. This could mean adding long-form responses, photographs, personal stories, and other forms of feedback about the same topic and from the same population.

As we saw in the earlier datasets, most data available for SproutCityTO is readily available. To mitigate their abstraction, SproutCityTO adds a new layer of creative and concrete data to complement the existing abstract content. In SproutCityTO, this is achieved by allowing community residents to add stories, pictures and poems about the UGSs. This brings in information about the land by introducing memories from the past, personal experiences, or simply by expressing emotional reflections about the place.

Since such information is not readily available, the interface and social part of SproutCityTO deliver opportunities for collecting such information. As a result, collecting unstructured narratives, reviews, personal memories, and poems about parks and green spaces in the city is an essential part of adding concrete information. To integrate it into the app, this information is tagged with a location to connect it to the rest of the datasets. The following screen displays the *What's happening?* page for Riverdale Park East, where users can add notes and short stories about the park.

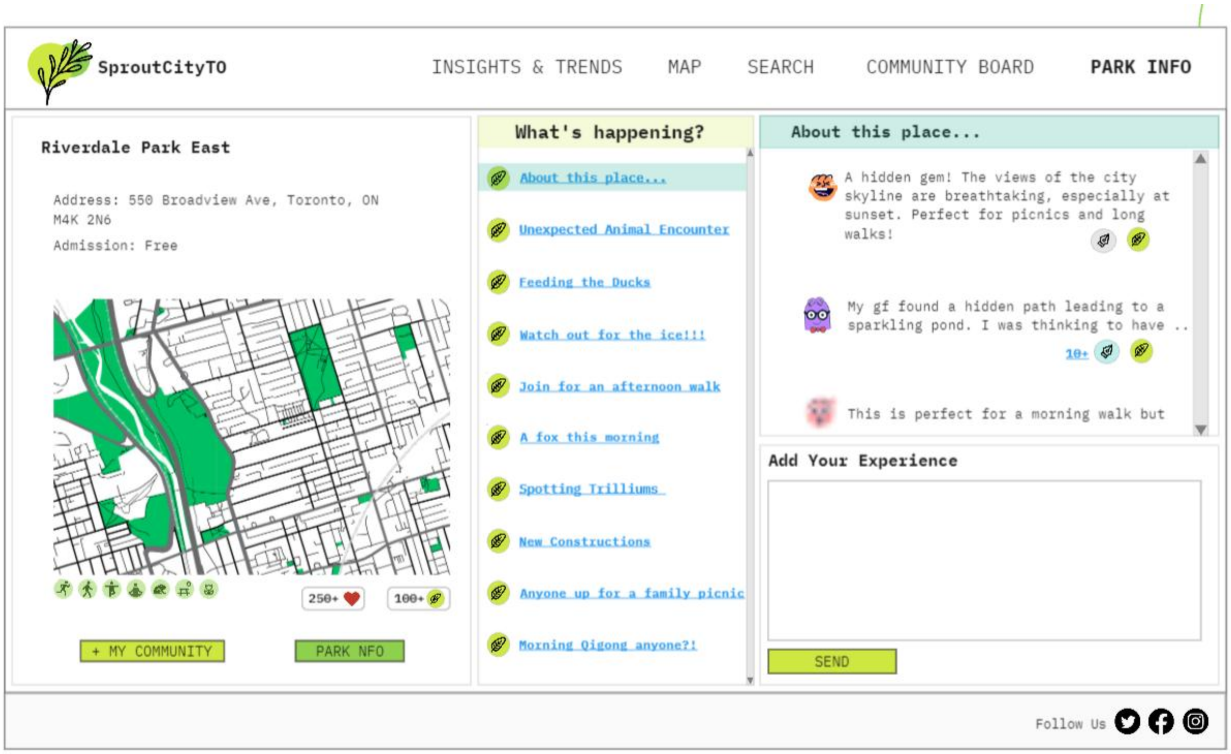

Figure 31. SproutCityTO, What's Happening Screen?

SproutCityTO provides different opportunities and screens for adding stories, pictures and poetry. This encourages storytelling by allowing residents to share their experiences on various screens. For instance, users can share their content by adding it to an interactive map.

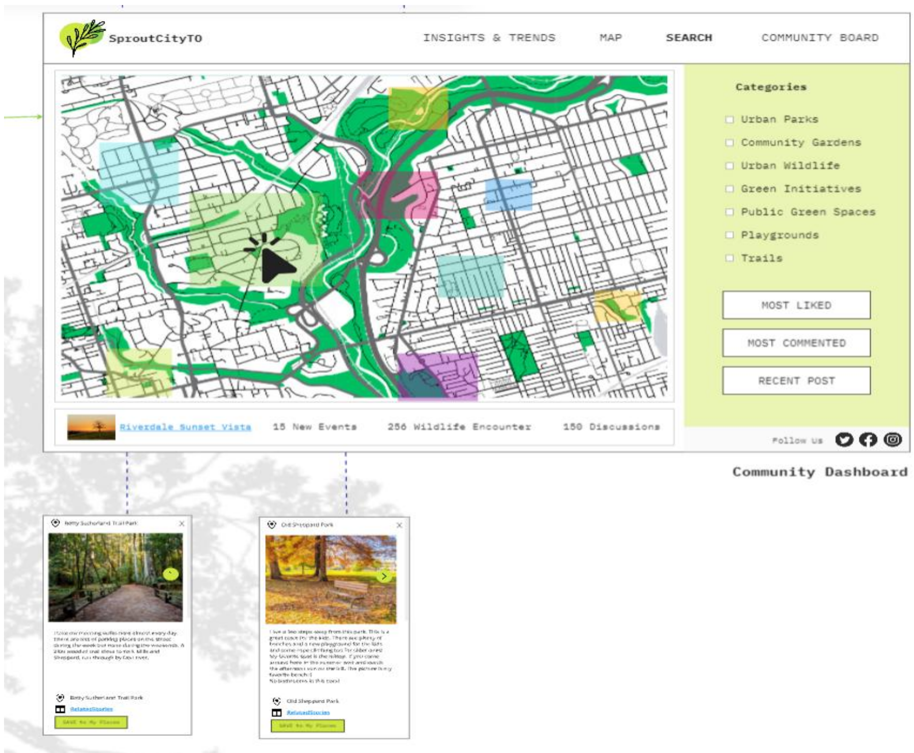

Figure 32. SproutCityTO, Users and Stories

Stories highlight the finer aspects of social life, cultural activities, and preferences in a community and reveal more than abstract data about the social identity of a place. That being the case, in the context of SproutCityTO, these narratives create a more nuanced and complex picture of how people connect and experience green spaces.

Similarly, historical context is often hidden from abstract data. Allowing residents to bring their memories and stories to the system and tag them to a green space enriches the app with historical events. Likewise, it displays how the parks have evolved through the years.

Sharing experiences through stories involves expressing values. This provides a more contextual picture of how these communities interact and evolve around these spaces. Adding context to green spaces means that they are not only physical features in the city, but also collections of tangible personal experiences.

After collecting enough stories or poems, SproutCityTO will regularly run an NLP (Natural Language Processing) analysis to detect sentiments, trends and nuances.

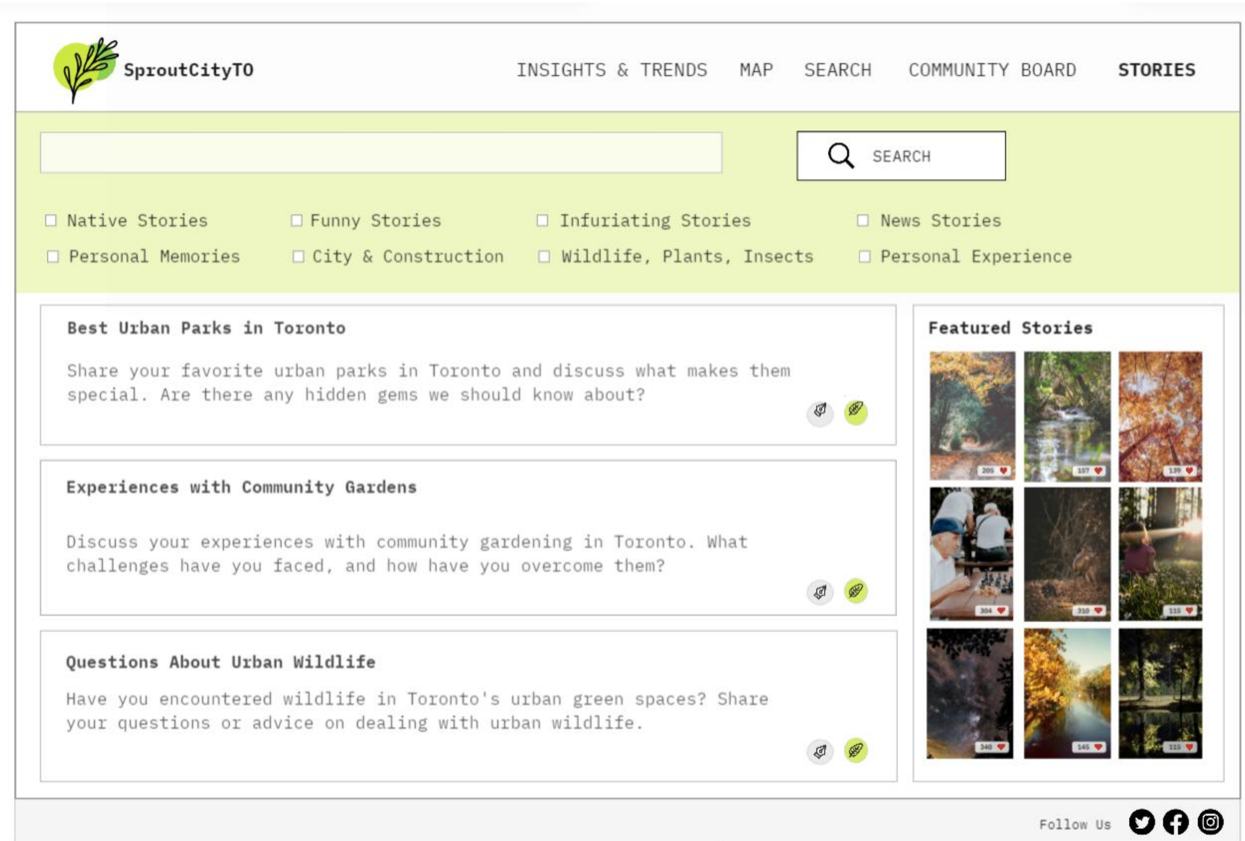

Figure 33. SproutCityTO, Search for Stories Screen

Principle 3 – Dynamic Data

A city never stops changing. People move, streets change, and pedestrian and car traffic adapt accordingly. Living in a dynamic environment means the data is never static and is always adjusting. As a result, the database design should include the possibility of integrating the element of time. For that reason, it's important to reflect time in the data design. This also allows for tracking changes, incorporating feedback mechanisms, and updating the system with later data without losing continuity. This ensures that models evolve with the changing conditions of the streets, population demographics, overall air quality and more. In the context of graph models, one solution is to add the factor of time as a node to the graph. This note will look like the following and connect to all existing nodes.

```
CREATE (t: Time {date: datetime(2024-07-07T00:00:00”)};
```

Here is a snapshot of the graph database with date and time added to the design.

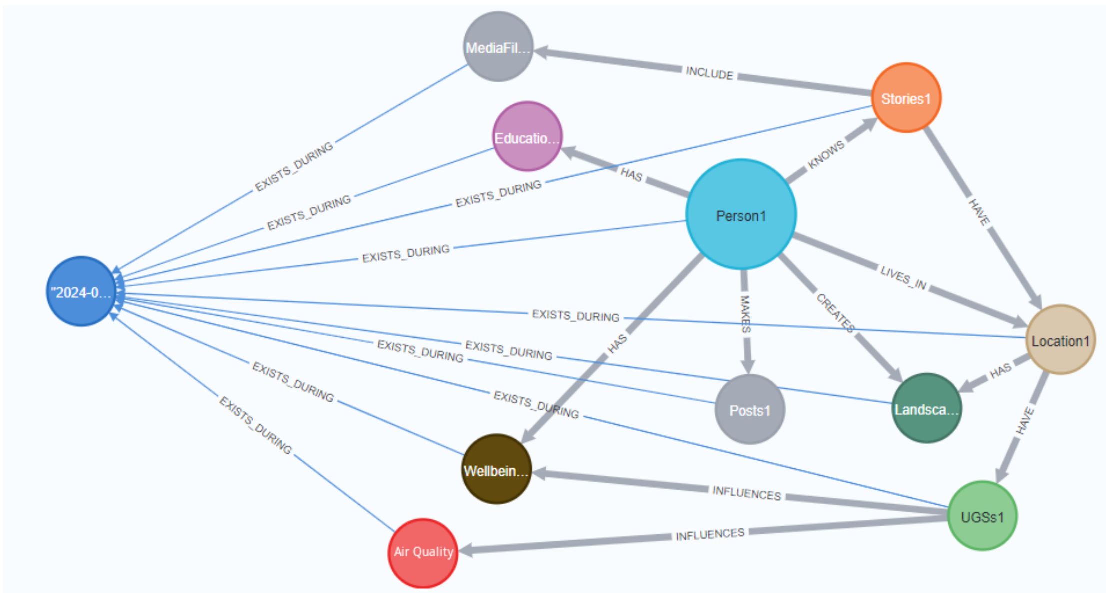

Figure 34. Close-up: Adding the Time Element

Working with a dynamic system requires including a feedback mechanism to investigate outcomes and changes. This aspect of dynamic systems means keeping track of responses and providing loops in the machine-learning process to account for changes and developments.

Principle 4 – Direct Experience

Including direct experience in empirical reasoning is an important part of the process model. We often hear the term, human-centred design. However, most such designs are not created with all players in mind. Furthermore, in Whitehead’s system, subjective experience is not limited to humans. This means understanding all the players in the system and considering their role in the app outcome. It also means balancing a human-centred plan with an eco-centred approach and handling the design by considering different players and their needs.

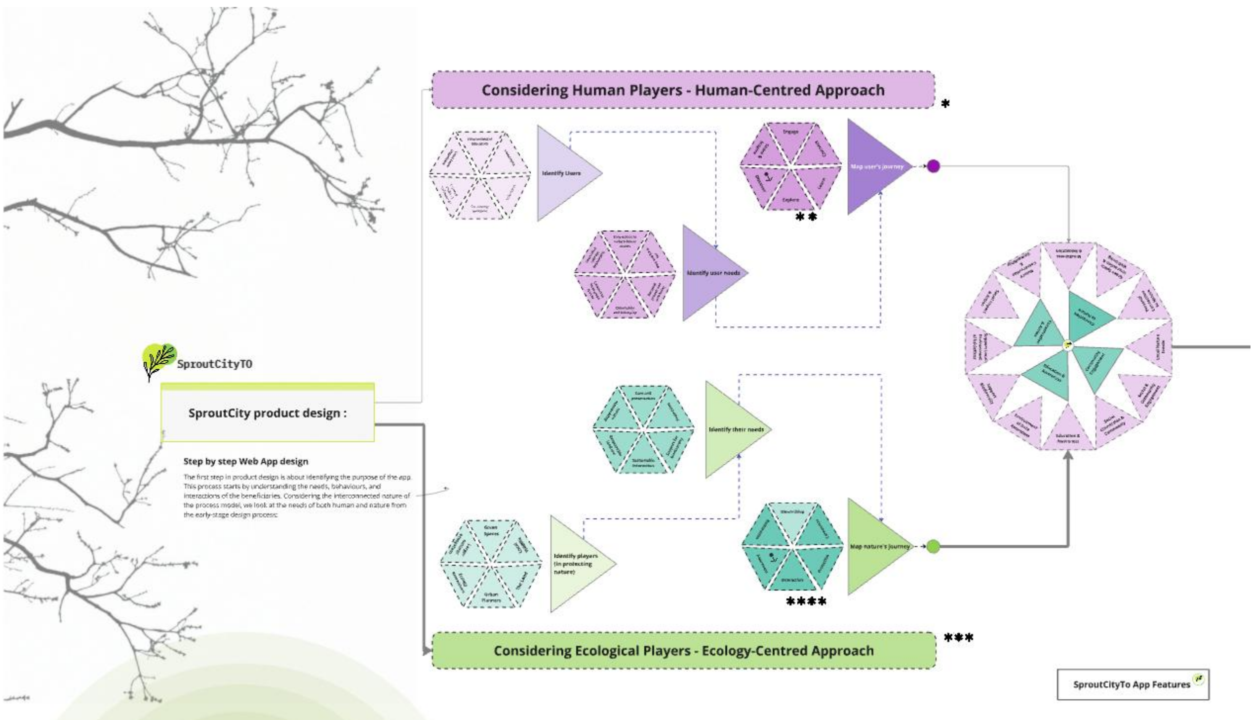

Figure 35. SproutCityTO, Users and Their Experience Map

A human-centred approach asks questions about user experience, such as: Who are the target users? What types of interactions interest them? What are their goals and incentives?

An eco-centred design is concerned with the needs of a healthy ecosystem. It aims to encourage native species and biodiversity in local UGS. Design questions could be: How does the app focus on biodiversity and promote sustainability? How can the app measure and track the health of green spaces? How can the app promote nature stewardship and encourage sustainable behaviours towards it?

The balance between a human-centred and eco-centred design takes us to the list of features that need to be included in the SproutCityTO. These features range from education and awareness to community engagement, connection to nature and conservation efforts toward UGS.

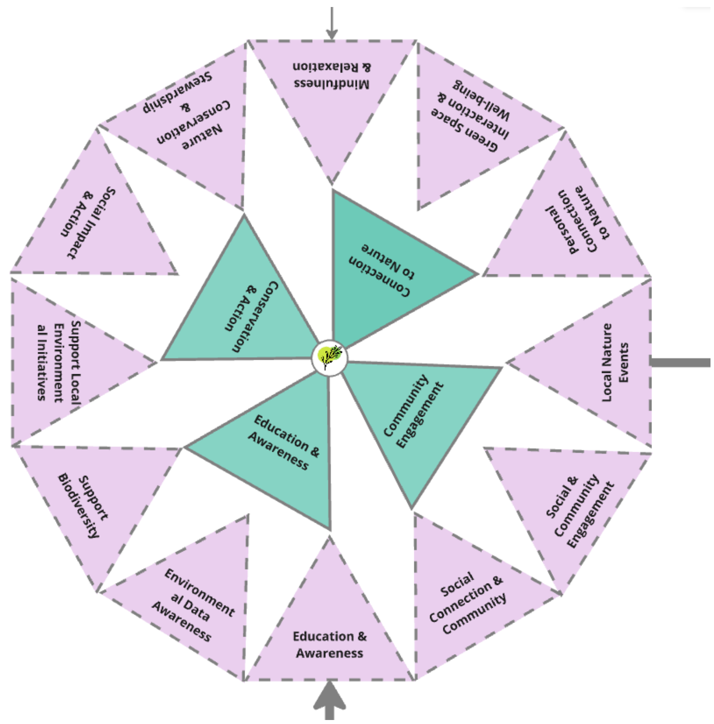

Figure 36. SproutCityTO, Discovering Features

The following page displays an example of such a feature implementation by sharing observations about encounters in nature. It allows for recording nature watching by sharing sounds, photos and descriptions. The following screen displays a summary of wildlife observation in Betty Sutherland Trail Park.

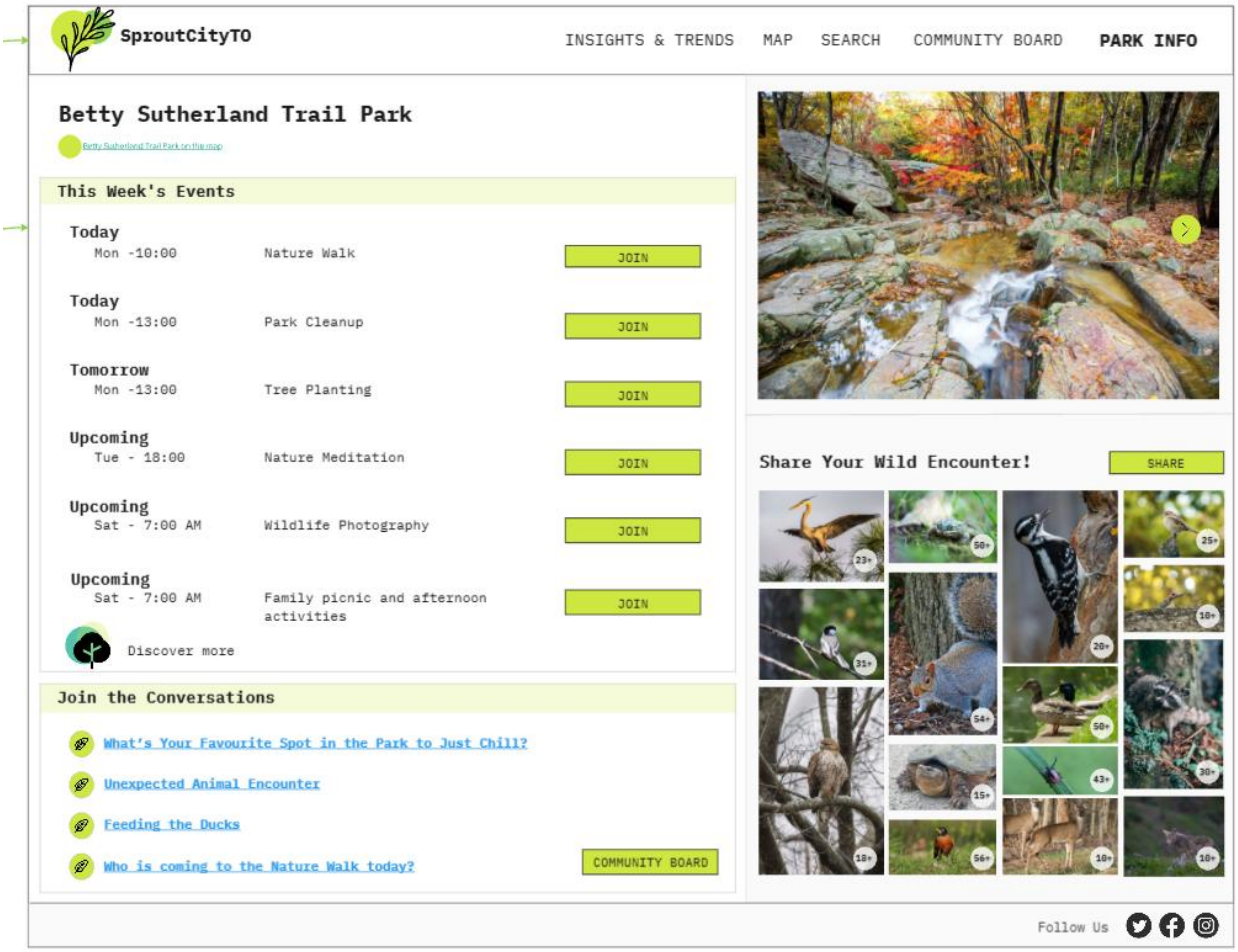

Figure 37. SproutCityTO, Park Landing Page Screen

Principle 5 – Values System

The PAI model is a design loaded with values. These values display the goals of different players in the system. In SproutCityTO, this translates to seeing human values of well-being and joy placed alongside eco-values, such as preservation and resilience.

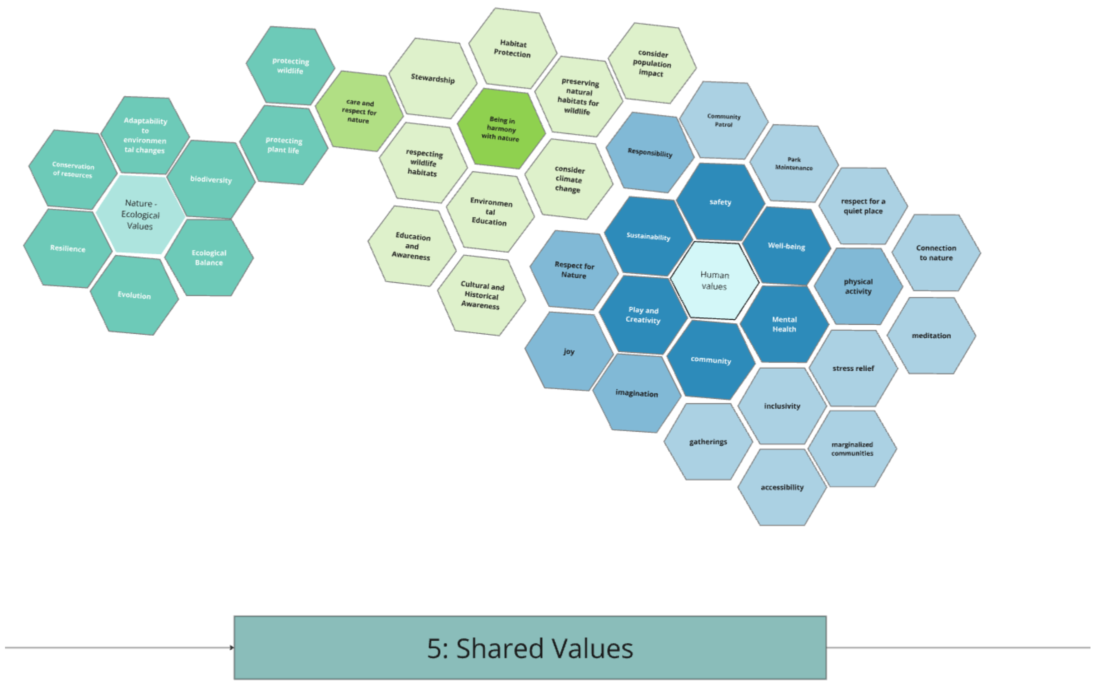

Figure 38. Considering Values for SproutCityTO

The PAI framework is a goal-oriented system that applies its values by creating a value engine. A value engine acts like a filter that determines what possibilities are preferred in the system. This engine could be implemented alongside machine learning and in a pipeline to direct decision-making.

Values could also be applied to the interface and overall app design. These could play out as prioritizing events, posts, and stories more aligned with the app's core values. For instance, posts and events that benefit the natural environment, such as tree planting and volunteer clean-up, get higher priority over those that don't offer such values. This could also mean removing posts that contain offensive or divisive content. In the long term, this translates to adjusting user behaviour towards the core values in the app.

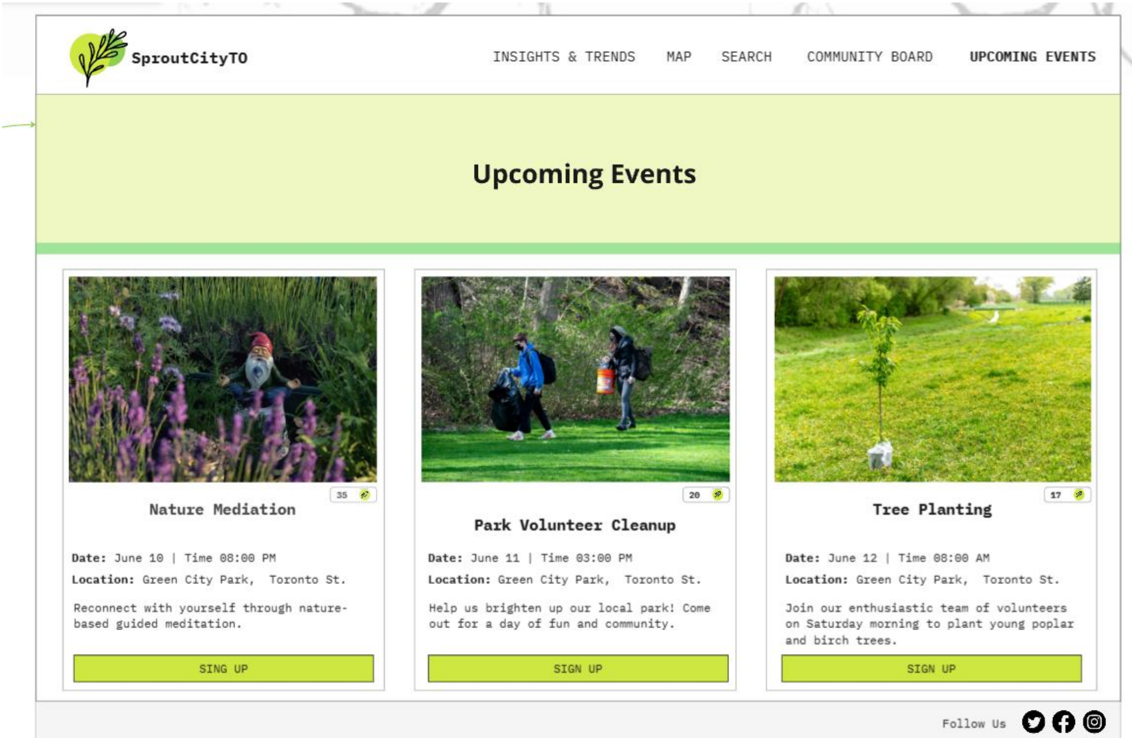

Figure 39. SproutCityTO, Upcoming Events Screen

Being unaware of the extent of possibilities and filtering based on values could have unintended consequences. That is why the app will contain feedback loops to monitor for unexpected outcomes. To do this, the PAI design requires a centralized memory system to maintain what is effective. The memory system evolves as it learns from the feedback and integrates new possibilities.

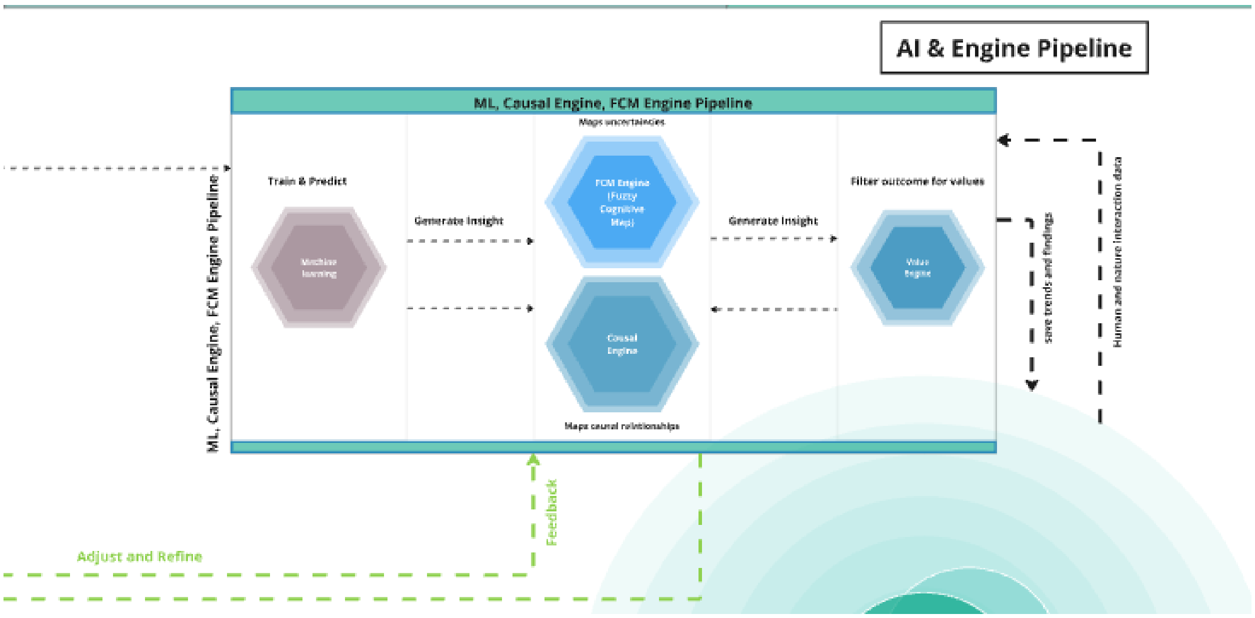

Figure 40. SproutCityTO, AI and Engine Pipeline

Principle 6- Prehension and Feedback

In PAI design, Prehension is about learning from the environment through a continuous feedback process. This uses old experiences to decide what works in the system or what should be adjusted and requires an unbroken supply of new data. In SproutCityTO, this is provided by the ability to update the system with the data and include a feedback loop to learn. This feedback could be user interactions, sentiments, or the data collected by users from the parks. It is also possible to use sensors to create direct access to some of the variables in and around the parks, such as pollution levels, recorded temperatures, etc.

Conclusion

The SproutCityTO app offers a case study for implementing PAI principles in its process. Combining coding logic with database design and asking different questions steers the design process toward a more context-aware and tolerant system. Similarly, the PAI principles ensure fairness and inclusivity of human and non-human voices in the system design.

Working through a feedback process involves including context and information about the changing environment to improve the app. The case study and the blueprint design offer the possibility of evaluating the impact of PAI principles in SproutCityTO. Technical requirements, such as running machine learning models on graph databases and incorporating feedback loops to change machine learning models, are not yet entirely established. At the same time, recent efforts are being made to include causal engines and run ML on graph databases.[213]

[213] "Causality Engine," www.cognizant.com, accessed March 10, 2025, https://www.cognizant.com/us/en/glossary/causality-engine; Clémentine Fourrier, "Introduction to Graph Machine Learning," 2023, https://huggingface.co/blog/intro-graphml.

Chapter 6: Conclusion

In the previous chapters, I applied process philosophy to AI design and mapped a framework to link its theoretical concepts with the technical aspects of AI. I developed and analyzed the SproutCityTO app as a case study to evaluate the applicability of this conceptual framework to change public behaviour and promote the connection between humans and nature. In this chapter, I summarize my findings about the concerns and challenges facing AI and how the process framework can help to integrate existing AI technology into a more relational and context-aware system.

Whitehead and AI

Whitehead's philosophy and metaphysics cover both ontology and cosmology. This means it concerns itself not only with existence and internal relations but also pays attention to the external connections and interactions that shape the universe.[214] This is a particularly effective viewpoint because it allows me to study AI design through its internal mechanisms and its relationships with the world around it. This approach is essential for understanding AI as a technical system and its broader role as a problem-solving 'mode of intelligence'. At the same time, process philosophy offers a unique opportunity to learn about the capacities and limitations of the technology.

Whitehead's process ontology is a scientifically informed philosophy.[215] At its core, it is built on the behaviour of particles in quantum mechanics and the idea of connectivity in

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[214] Hosinski, *Stubborn Fact and Creative Advance*, 27.

[215] McHenry, *The Event Universe*, 29.

electromagnetic fields.[216] This is not a world of objects and subjects. Rather, it's a unifying universe made of interacting entities. In the process universe, reality is created through the interaction and exchange of information between actual entities. As a result, objects are only recognized through their interactions with other events that shape their "life history."[217]
The process world is also a "becoming" universe, where everything evolves and becomes. Applying this perspective to AI is especially valuable because it not only opens new possibilities to see the technology in a different light but also undermines the existing power balance in the creation and formation of AI. Using the process approach allows relationality to modify and even replace the power structure formed by developers, AI companies and other stakeholders. Thus, Whitehead's approach to reality offers a path to view AI critically and also to see alternative possibilities to re-imagine the technology and create an applicable model for seeing AI as a more dynamic and integrated system.

Autonomous AI or Collaborative Machines

Much publicity heralds the arrival of next-generation General Artificial Intelligence (GAI) that will surpass human brainpower. In his proposal to the famous Dartmouth Conference, John McCarthy defined the term intelligence as the computational ability to achieve goals in the world.[218] But this computational ability doesn't fully encompass everything we know as human intelligence.

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[216] Lowe, *Understanding Whitehead*, 118.

[217] Whitehead, *Science and the Modern World*, 106.

[218] Monett et al., "John McCarthy's Definition of Intelligence."

Much of what we have incorporated into making AI can be summarized into three categories: rule-based AI, connected AI, and a hybrid of the two models. A 'rule-based system' is a top-to-bottom approach that focuses on human behaviour to find step-by-step instructions and apply them to problem-solving in AI.[219] Connected AI, also known as deep learning, is a bottom-up approach and learns by finding patterns in human behaviour. The third category is NeuroSymbolism, which brings the two previous categories into one system. None of these steps is outside the computable parts of human behaviour. Here, all three categories are attempts to mimic human behaviour but do not constitute intelligence.[220]

One of the strengths of human intelligence is its ability to sift through the experience of inhabiting a human body and function in a society with a history, cultural values, common sense and social contracts. None of this hidden knowledge would be available to us without the locality, limitations, and physicality of existing as a human being. The idea of intelligence in AI is a misnomer, since the intelligence mode in AI is a disembodied, 'de-situated' apparatus that works only with what could be called the abstract footprints of human behaviour.[221] Looking at the three AI categories outlined above, even the fastest and smartest machine learning algorithms miss the common sense, causal reasoning and intuitive insights that come naturally to a human being. They are gained only through a lived experience in a social environment.

In *What Computers Can't Do: The Limits of Artificial Intelligence*, Hubert Dreyfus uses an analogy to address the idea of progress and enthusiasm in AI. He writes, "The first man to

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219 Also, a heuristic approach

220 Possati, *Unconscious Networks*; Solomonoff, "The Meeting of the Minds That Launched AI - IEEE Spectrum"; A. Newell and H. Simon, "The Logic Theory Machine--A Complex Information Processing System," *IEEE Transactions on Information Theory* 2, no. 3 (1956): 61–79, https://doi.org/10.1109/TIT.1956.1056797; Marcello Pelillo and Teresa Scantamburlo, eds., *Machines We Trust: Perspectives on Dependable AI* (The MIT Press, 2021), 106; Artur d'Avila Garcez and Luis C. Lamb, "Neurosymbolic AI: The 3rd Wave," arXiv:2012.05876, preprint, arXiv, December 16, 2020, http://arxiv.org/abs/2012.05876.

221 It lacks context and location.

climb a tree could claim tangible progress toward reaching the moon. Rather than climbing blindly, it is better to look where one is going. It is time to study in detail the specific problems confronting work in artificial intelligence and the underlying difficulties that they reveal."[222] Thus, we need to question the purpose behind creating intelligent machines. Are we developing AI to solve our complex problems, or are we attempting to replicate a human-like machine? In the end, it seems more pragmatic to accept AI technology within its limitations and instead create a set of protocols to collaborate and transfer human modes of intelligence to machines. This is what the PAI design framework is designed to do.

PAI Framework

PAI works by accepting the limitations of AI machines and instead designs a set of guidelines to transfer human-derived knowledge to the machine. It ties the empirical and the logical with the relational and non-computational aspects of human intelligence.

PAI is also a pluralistic model that accounts for the presence of different players in AI design. AI design is often hailed as human-centred, but it is mostly 'single-perspective-centred' and evolves around the limited point of view of its designers, developers or funding bodies. In contrast, PAI accounts for relationality from the early stages of its design, from data to consider and include multiple subjective experiences. Accordingly, it is a multi-centred design and balances different players within the system. The PAI works more like a human because its learning is based on continuous improvement. Thus, it learns from its initial bias and shortcomings to continuously add new information and improve.

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[222] Hubert L. Dreyfus, *What Computers Can't Do: The Limits of Artificial Intelligence*, Rev. ed. 7th print, Perennial Library (Harper & Row, 1986), 12.

The process-oriented framework advocates mapping and transferring different facets of human knowledge to AI systems. The ability to map common sense, causal reasoning, and values to translate them to an AI system determines the ability of this work to succeed. Living in a dynamic universe, common sense and causal maps cannot be entirely fixed to a single point in time. For this reason, the feedback loop and continuous co-creation and reworking of these knowledge maps are essential in PAI design.

Because the feedback loop and continuous learning adjust for new information and new interactions, the PAI framework offers an opportunity to solve problems of fairness and power imbalance inherent in the current structure of AI. The continuous learning and feedback process correct course for such imbalances. This also means that a PAI design is always dependent on human collaboration and user response to adjust its output.

Similarly, creating a central memory allows the PAI system to retain data from previous tasks and apply it to later decision-making. Most AI systems are task-oriented and do not have a central memory. This means there is little continuity between the decisions. Instead, each decision is made independently, based on the patterns it processes. In contrast, retaining the memories of past interactions and using them in decision-making is central to the PAI framework.

To summarize, PAI principles offer a set of protocols to reintroduce a missing part of the "human" puzzle back into the AI system. PAI fills the knowledge by working in a continuous process to adjust and improve. Similarly, building a strong values system into AI machines ensures that long-term goals are aligned with human values. Looking at the future, AI is not necessarily an autonomous machine but rather in the process of becoming a co-creator that could help humans imagine solutions to problems and test outcomes more efficiently.

Applying the process model to AI requires a fresh perspective toward the technology. This vision is about moving away from the andromorphic obsession with AI and viewing it as an effective tool for solving complex problems. This means establishing structured protocols to facilitate human and AI collaboration through co-creation.

Humanizing Big Data

AI practitioners often integrate the social aspect of their work by portraying human data as singular, straightforward, and stable, overlooking the chance to fully acknowledge the influence of power dynamics, systemic discrimination, and social inequalities in the interpretation of social categories.[223] In *Humanizing Data*, Colin Strong argues that standard big data overlooks a crucial aspect in its pursuit of data-driven insights by assuming that data points represent individuals, whereas individuals are far more complex than mere data points.[224]

Data science methodologies often overlook the embodied, interactive aspect of diversity and its evolving significance across different temporal and spatial contexts.[225] Behind every data point in every chart or diagram, there is an individual with many other characteristics. Just like a character in a story, the data can be animated with the use of human stories.[226] Including a layer

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[223] Joyce et al., "Toward a Sociology of Artificial Intelligence"; Safiya Umoja Noble, *Algorithms of Oppression: How Search Engines Reinforce Racism* (NYU Press, 2018), https://doi.org/10.2307/j.ctt1pwt9w5; Taylor M Cruz, *Perils of Data-Driven Equity: Safety-Net Care and Big Data's Elusive Grasp on Health Inequality*, 2020, https://journals.sagepub.com/doi/full/10.1177/2053951720928097.

[224] Colin Strong, *Humanizing Big Data: Marketing at the Meeting of Data, Social Science and Consumer Insight* (Kogan Page, 2015), 19–20.

[225] Joyce et al., "Toward a Sociology of Artificial Intelligence"; Leslie A. Dubbin et al., "Cultural Health Capital and the Interactional Dynamics of Patient-Centered Care," *Social Science & Medicine (1982)* 93 (September 2013): 113–20, https://doi.org/10.1016/j.socscimed.2013.06.014; Elyas Bakhtiari et al., "Institutions, Incorporation, and Inequality: The Case of Minority Health Inequalities in Europe," *Journal of Health and Social Behavior* 59, no. 2 (2018): 248–67, https://doi.org/10.1177/0022146518759069.

[226] Nancy Duarte, *Data Story: Explain Data and Inspire Action through Story* (Ideapress Publishing, 2019), 227.

of personal stories and connecting them to abstract measures creates empathy and understanding toward UGS, for example.

In process ontology, data is not external to a process. Instead, it is an integral part of it, always changing and being exchanged among processes. Consequently, data can never be fully extracted and stored away. Instead, it should be continuously observed and corrected according to evolving changes. This means replacing the vision of fully automated AI with a collaboration between human agents and AI systems. This might mean that the human element can never be removed from AI.[227] Consequently, AI's effort to imitate the human thinking process might be better focused through integration and a more collaborative approach. Ultimately, combining AI capabilities with holistic human thinking provides the best possible combination for solving problems.

In empirical reasoning, observing an object, like a stone, is about measuring a passive substance, void of meaning. All information about this stone is reduced to its passive elements. Doing the same study using Whitehead's process approach takes us on a different path. Saying that the stone is grey is an abstract statement. The mechanism in the eye experiences vision through cells of the retina, and then the sequence of nerve circuits between the eye and the brain translates whatever is out there into an image of a stone. Thus, a direct relationship between the stone and the perceiving colour is mediated by the transmission process.[228] In other words, data cannot be entirely separated from perception and the human element. Thus, collaboration between the AI system and the human element is essential to successfully "seeing" a stone and interpreting the data correctly.

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[227] Titir Pal, "Can Big Data Be Humanized?," *Absolutdata*, 2016, https://www.absolutdata.com/blog/can-big-data-be-humanized/.

[228] Whitehead, *Process and Reality*, 118.

Efforts in the development of AI have evolved around the idea that both humans and artifacts can be described in terms of their outward behaviours.[229] This reductionist perspective ignores the internal functioning of both the human mind and of technology, in favour of analyzing its external relationships.[230]

The widespread adoption of the reductionist perspective in AI development has resulted in assumptions about the objectivity and all-encompassing role of data. This has led to conclusions such as "data is raw" or "letting the data speak for themselves."[231] However, looking at practical examples shows that data is more than a collection of facts and requires "conceptual and philosophical ways" to make sense of its role in AI systems.[232] This requires questioning "the nature of data, how they are being produced, organized, analyzed and employed, and how best to make sense of them and the work they do."[233] To a certain degree, big data and AI methods challenge the "established epistemologies" of scientific research and make it more difficult to draw unbiased outcomes from data.[234]

In process ontology, nothing is passive, and data is always about communication between subjects. Adding the subjective element to AI requires introducing contextual information, like personal stories and including human collaboration in the process to account for embodied understanding and subjectivity to understand reality beyond material substance. Embracing the

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229 Herbert A. Simon, *The Sciences of the Artificial*, 3rd ed (MIT Press, 1996).

230 Lucy Suchman, "Demystifying the Intelligent Machine," in *Cyborg Futures: Cross-Disciplinary Perspectives on Artificial Intelligence and Robotics*, ed. Teresa Heffernan, Social and Cultural Studies of Robots and AI (Springer International Publishing, 2019), https://doi.org/10.1007/978-3-030-21836-2_3.

231 Peter Gould, "Letting the Data Speak for Themselves," *Annals of the Association of American Geographers* 71, no. 2 (1981): 166–76.

232 Rob Kitchin, "Big Data, New Epistemologies and Paradigm Shifts," *Big Data & Society* 1, no. 1 (2014): 205395171452848, https://doi.org/10.1177/2053951714528481.

233 Rob Kitchin and Tracey P Lauriault, *Towards Critical Data Studies: Charting and Unpacking Data Assemblages and Their Work*, 2014, 19.

234 Kitchin, "Big Data, New Epistemologies and Paradigm Shifts."

contextual information and collaborative approach, AI systems can add the complexities of subjective and embodied experience to their empirical reasoning. This, in turn, can create a technology that is more context-aware and more connected to real human experience.

Future Directions

The future of AI and process ontology brings forward several possibilities at the intersection of technology and philosophy. First, deeper integration of processes into AI requires adopting a more dynamic approach to data collection and data visualization. Adapting the idea of data as a continuous dynamic requires rethinking data models and adapting a more dynamic data design in AI. This also means the AI system is not entirely an engineering project and must include more diverse aspects of human experience by engaging artists and designers in AI design. This type of developmental approach creates multiple possibilities for AI outside its current rigid domain. Bringing a process approach to AI opens the possibility of reevaluating ethical concerns and ensuring the integration of human values into AI systems.

Descartes's "bifurcation of nature" removes value from the physical world. Instead, it places the notion of values within the mind, independent of things, independent of nature. Transferring values from nature to the mind rendered them subjective and not quite part of the system of facts.[235] As a result, values are entirely overlooked in traditional AI systems. This absence of values reflects the ethical and moral challenges commonly observed within AI technology.

[235] George Morgan, "Whitehead's Theory of Value," *International Journal of Ethics* 47, no. 3 (1937): 308–16.

In the PAI framework, values are not separate from facts. They are not created out of subjective interpretations. Rather, the nature of the object is the source of its values.[236] In other words, "to be actual is to have value."[237] In the process framework, values are embedded within the process of becoming and in the process of prehension. Similarly, ethics are a consequence of the interconnectedness and collaboration of actual entities. This is where the PAI framework provides a clear direction to solve complex problems that require considering context and inter-relationality in their solution. This approach to AI could be particularly beneficial when a clear-cut statistical answer does not provide the best outcome. For example, working with participants with different physical abilities or working on a project that requires historical context would be best considered through PAI.

PAI in Critical Discourse

An interesting future direction in expanding on the PAI framework is to position it in conversation with contemporary critical discourses, such as Feminist Technoscience and Indigenous-AI. Each of these theories invites different forms of relationality into understanding technology and examining its connection to humans, their agency, and their broader social impacts. For instance, Feminist Technoscience theorists bring interrelations and feminist critique into examining the role of science and technology. Donna Haraway's notion of the cyborg blurs the boundaries between human and machine. Similarly, Karen Barad's definition of "intra-action" focuses on exchange and transformation through relations.

[236] Holmes, "A History of Philosophy | 61 Whitehead's Process Philosophy."

[237] Brian G. Henning, "Saving Whitehead's Universe of Value: An 'Ecstatic' Challenge to the Classical Interpretation," *International Philosophical Quarterly* 45, no. 4 (2005): 447–65, https://doi.org/10.5840/ipq200545440.

Another fertile future possibility is placing PAI in conversation with Isabelle Stengers' ideas, especially her writings on the role of speculation and world-making in imagining future possibilities that were not thinkable otherwise. Stengers defines cosmopolitics as a place where imagination, experimentation, and world-making become political and challenge the single worldview perspective. This dissertation project can also be considered an exercise in cosmopolitics in Stengers' sense, rejecting a single worldview on AI and expanding its understanding through map-making and the creation of scaffoldings where artists can participate in its design process and question its inner workings.[238] This opens the door for further engagement with her work.

The Indigenous Knowledge (IK) system is another exciting future possibility for expanding the discussion around the PAI framework.[239] Understanding AI through Indigenous epistemology offers plurality within the IK system and introduces protocols to maintain social and environmental contexts within the technology. Leroy Little Bear's writing on Blackfoot metaphysics also offers a rich perspective in understanding AI technology by examining the connection between Indigenous languages and the scientific worldview. Consequently, the conversation and comparison between the PAI framework and the Indigenous Protocols intersect and open new possibilities for conceptual developments.[240]

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[238] Mario Blaser, "Is Another Cosmopolitics Possible?" *Cultural Anthropology* 31, no. 4 (2016): 545–70, https://doi.org/10.14506/ca31.4.05; Isabelle Stengers, "Reclaiming Imagination: Speculative SF as an Art of Consequences," December 24, 2018, https://www.natcult.net/interviews/reclaiming-imagination-speculative-sf-as-an-art-of-consequences/.

[239] Jason Edward Lewis et al., "Abundant Intelligences: Placing AI within Indigenous Knowledge Frameworks," *AI & SOCIETY* 40, no. 4 (2025): 2141–57, https://doi.org/10.1007/s00146-024-02099-4.

[240] Angie Abdilla et al., "Indigenous Protocol and Artificial Intelligence Position Paper," preprint, Concordia University Library, 2020, https://doi.org/10.11573/SPECTRUM.LIBRARY.CONCORDIA.CA.00986506; Leroy Little Bear and Ryan Heavy Head, "A Conceptual Anatomy of the Blackfoot World," *ReVision* 26, no. 3 (2004): 31–39; Lewis et al., "Abundant Intelligences."

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