

DATA-DRIVEN ENVIRONMENTAL ART FOR ENHANCING
USERS' PRO-ENVIRONMENTAL BEHAVIOR

by

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ART ENVIRONNEMENTAL BASÉ SUR LES DONNÉES – POUR RENFORCER LE COMPORTEMENT PRO-ENVIRONNEMENTAL DES USAGERS DES BÂTIMENTS

Saba KAKAVAND

RÉSUMÉ

Les bâtiments représentent une part importante de la consommation de ressources. Bien que les technologies des bâtiments intelligents, incluant les systèmes et équipements automatisés, aient amélioré l'efficacité opérationnelle, le comportement des usagers demeure une variable déterminante. L'automatisation crée souvent l'illusion que la durabilité peut être atteinte sans participation humaine; pourtant, les choix quotidiens ont encore un impact considérable, souvent sous-estimé dans les simulations de performance des bâtiments. Le principal défi consiste à rendre les données du bâtiment suffisamment significatives et attrayantes pour encourager un comportement éco-responsable. L'art environnemental fondé sur les données vise à encourager la réflexion et l'action face aux enjeux écologiques en suscitant l'émotion et la conscience, plutôt qu'en prescrivant des comportements.

Cette thèse examine dans quelle mesure l'art environnemental fondé sur les données peut renforcer l'engagement émotionnel et cognitif des usagers des bâtiments vis-à-vis des données de durabilité du bâtiment. Pour ce faire, un cadre méthodologique data-to-art est proposé, représentant la durabilité comme une transformation allant du fonctionnement des systèmes du bâtiment vers l'expérience vécue des occupants. Ce cadre repose sur : (1) l'exploitation de signaux de durabilité issus des équipements techniques ou des espaces occupés (p. ex. débit d'air de ventilation, consommation énergétique, température, signaux d'occupation), (2) leur interprétation en tant qu'indicateurs du fonctionnement des systèmes et des conditions intérieures résultantes, et (3) leur traduction en formes sensorielles perceptibles reflétant l'effort requis pour atteindre le confort des occupants. L'installation *Garden of Sensors* a été développée et présentée dans une bibliothèque universitaire comme une mise en œuvre partielle de ce cadre, combinant le débit d'air de ventilation comme indicateur opérationnel lié à l'énergie et la température ambiante comme proxy du confort thermique, à travers des représentations inspirées de la flore indigène vulnérable.

Une évaluation qualitative, mobilisant l'esthétique empirique et la psychologie environnementale, a permis d'analyser les réponses émotionnelles, les réflexions et les intentions comportementales. Une enquête menée auprès de 43 participants indique que des émotions positives telles que l'inspiration et l'espoir sont le plus souvent associées à un engagement réflexif et à une volonté d'adopter des comportements plus durables, tandis que des émotions comme la culpabilité et la mélancolie tendent à susciter une introspection sans intention clairement formulée. Le cadre data-to-art développé dans cette étude est flexible,

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permettant l'intégration de divers types de données du bâtiment et son adaptation à des formats multisensoriels tels que le son, l'haptique ou l'interactivité. Cette thèse contribue aux travaux sur la communication en durabilité en montrant comment l'art environnemental fondé sur les données peut compléter les systèmes techniques par une dimension émotionnelle, offrant ainsi un nouveau modèle de conception centrée sur l'utilisateur.

Mots-clés: consommation énergétique, comportement pro-environnemental, psychologie environnementale, émotions, art environnemental

DATA-DRIVEN ENVIRONMENTAL ART TO ENHANCE USERS' PRO-ENVIRONMENTAL BEHAVIOR

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ABSTRACT

Buildings account for a significant share of resource consumption. While smart building technologies, including automated systems and equipment, have improved operational efficiency, user behaviour remains a critical variable. Automation often creates the impression that sustainability can be achieved without human involvement, yet daily choices still have a considerable impact, often underestimated in building performance simulations. A central challenge is making building data meaningful and engaging enough to encourage eco-conscious behaviour. Beyond presenting technical information, the goal is to create representations that inspire reflection and action. According to the literature, data-driven environmental art has proven effective in opening communication around ecological issues and public engagement. Rather than prescribing behaviour, art invites users to feel and reflect on their relationship with the environment.

This thesis investigates whether data-driven environmental art can enhance building users' emotional and cognitive engagement with building sustainability data. To address this, a data-to-art framework is proposed that represents sustainability as a transformation from building system operation to an indoor experience. The framework operates by (1) taking sustainability-relevant building signals originating at the equipment level or within occupied spaces (e.g., ventilation, airflow, energy consumption, temperature, occupancy signals), (2) interpreting them as indicators of system operation and resulting indoor conditions, and (3) translating these signals into perceptible art forms that reflect the effort required to achieve users' comfort. The Garden of Sensors installation was developed and exhibited in a university library, as a partial implementation of this framework, combining ventilation airflow as an energy-related operational indicator and room temperature as a proxy for thermal comfort with representations inspired by vulnerable native flora species.

A qualitative evaluation, drawing on empirical aesthetics and environmental psychology, assessed emotional responses, reflections, and behavioural intentions. A survey of 43 participants indicated that uplifting emotions such as inspiration and hope were most often associated with reflective engagement and willingness to adopt sustainable habits, whereas emotions such as guilt and melancholy tended to prompt introspection without clear intention. The data-to-art framework developed in this study is flexible, allowing integration of diverse building data and adaptable to multisensory formats such as sound, haptics, or interactivity. This thesis contributes to sustainability communication by demonstrating how data-driven

environmental art can complement technical systems with emotional engagement, offering a new model for occupant-centred design.

Keywords: building sustainability, pro-environmental behaviour, environmental psychology, emotions, environmental art

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LIST OF ABBREVIATIONS

AC	Awareness of Consequences
AHU	Air Handling Unit
AI	Artificial Intelligence
AR	Ascription of Responsibility
BACnet/IP	Building Automation and Control Network over Internet Protocol
BAS	Building Automation System
BMS	Building Management System
CSV	Comma-Separated Values
DDT	Dichloro-Diphenyl-Trichloroethane
DSR	Design Science Research
DSRM	Design Science Research Methodology
FC	Field Controller
HVAC	Heating, Ventilation and Air Conditioning
IP	Internet Protocol
MS/TP	Master-Slave/Token-Passing
NAM	Norm Activation Model
NAE	Network Automation Engine
NEE	Network Engine
PEB	Pro-Environmental Behavior
SQL	Structured Query Language
TPB	Theory of Planned Behavior/Behaviour
UTA	Unité de Traitement d'Air/ Air Handling Unit
VAV	Variable Air Volume
VBN	Value-Belief-Norm (theory)
VMA	VAV Modular Assembly

INTRODUCTION

Modernist architect Le Corbusier once described buildings as “machines for living in,” and that idea has continued to evolve alongside new technologies and challenges. In the 1980s, computer technology brought us “smart” buildings, with built-in systems and automated controls. Today, buildings have become even more advanced, filled with embedded sensors tracking everything from heat and water use to electricity and even oxygen levels. The Energy Performance Building Directive established the idea of "smart buildings" with the intention of fostering user involvement, renewable energy production, and energy flexibility (Al Dakheel et al., 2020). These automations across different disciplines have profoundly transformed building culture, pushing it toward smarter systems and greater control over resource consumption. The aim is to create a higher-quality built environment and more optimal use of resources. However, this has also resulted in a diminished sense of human agency and, consequently, a reduced sense of responsibility for the impact of building users’ activities on the built environment. Harvard professor Michele Addington points out that while we keep chasing the latest high-tech systems, new technology often outpaces our ability to use it wisely (Holmes, 2007). Resource consumption in building heating and cooling may rise in tandem with global temperatures because of climate change. Furthermore, energy prices shift in response to the socioeconomic effects of climate change and associated policies, which further affect the operating expenses of buildings in the future (Holmes & Reinhart, 2013). Scientists have been researching how to modify environmental behavior and how to communicate environmental challenges for a long time (Gifford, 2011; O’Neill & Day, 2009; Steg & Vlek, 2009; Bamberg & Möser, 2007; Swim et al., 2011). As Canadian scientist and environmentalist David Suzuki (2002) explains, sustainability means “doing things better, not doing without.”

Since the environment has long inspired artistic practice, the 1960s saw its evolution into a movement aimed at improving the relationship between humans, nature, and art. Environmental art has been described as a key approach to facilitate communication around environmental issues, linking sustainability concerns in buildings to users’ attention and awareness. It can be defined as any artwork that raises awareness of people’s relationship with

nature and prompts discussion and/or action on environmental issues (Marks, 2015). Over time, various forms of environmental art have emerged, each shaped by the issues of its era. More recently, the rise of digital technologies and the abundance of information have given rise to data-driven environmental art, which employs large datasets, artificial intelligence (AI), and other advanced technologies (Zeilinger, 2025). This artistic format uses environmental data not for technical monitoring but as material for aesthetic and emotional expression. In this research, we suggest that data-driven environmental art can interpret building performance data from smart buildings, thereby contributing to data literacy by making such data sensible through artistic practices. Automation in smart systems has facilitated easy access to large datasets, creating opportunities not only for automation but also for informing and engaging building users. Despite these advances, most prior studies have relied on technical interfaces such as dashboards, charts, or abstract data maps to communicate sustainability information (Ceccarini et al., 2022; Holmes, 2007; Olsen, 2014; Timm & Deal, 2016). While these approaches improve clarity and usability, they remain largely confined to informational feedback and overlook the emotional or symbolic dimensions of user engagement. Few studies have investigated art-based or emotionally expressive forms of data representation, and even fewer have assessed their impact on occupants' cognitive reflection or pro-environmental intentions. Our focus is on data-driven environmental art, a digital extension of the broader environmental art movement. While environmental art in buildings has been studied, little research has examined its effect on the sustainable behavior of occupants. This research addresses that gap by exploring how a data-driven environmental art installation influences building users' pro-environmental behavior.

0.1 Purpose of Study

The goal of this study is to introduce a new way of using building data to promote pro-environmental behaviour among occupants. We position environmental art as a legitimate medium for engaging users with sustainability. The research hypothesis is that an emotionally engaging art installation, which metaphorically highlights the interconnected impact of building resource consumption on the natural environment, can make communication between data and users more impactful by reminding occupants that their activities directly affect the

building's sustainability. A digital eco-artwork based on building data can connect user actions to the broader natural context in ways that activate both cognition and empathy. Prior studies support this approach, showing that emotionally engaging representations reduce the psychological distance between human activities and their impacts (Sommer & Klöckner, 2021), and that different emotions evoked by environmental art can influence cognition and ultimately shape pro-environmental behaviour (Sommer et al., 2019).

Beyond raising awareness, this research seeks to enable users to feel the data through an aesthetic and sensory experience. It investigates environmental art through the case of a digital installation titled Garden of Sensors. The installation creates an opportunity for building users at the university library to relate to the building through sensor and equipment data, thereby enhancing their sense of responsibility. Local vulnerable flora, specifically wood lilies, serve as the installation's metaphorical interface, reflecting the impact of building users' activities on the natural environment.

There has been little empirical analysis of the impact of environmental art on its audience. This case study provides an opportunity to address that gap by examining the following research questions:

- How can building sensor data be transformed into meaningful environmental art forms that engage occupants?
- How does experiencing a digital, data-driven environmental artwork contribute to pro-environmental behaviour?

This research suggests that environmental art offers an engaging and imaginative format that can complement environmental awareness and deliver sustainability messages. The study investigates the impact of interacting with environmental art on individuals' pro-environmental behaviour through their engagement with smart building data. In doing so, it explores environmental art as a practical medium for creating inclusive spaces that foster responsibility and shared values of sustainability among building users.

0.2 Significance of Research

This multidisciplinary research draws on smart building sustainability, environmental psychology, and art to advance understanding of how occupants can be engaged through environmental art. It incorporates theoretical paradigms from multiple disciplines: Ajzen's Theory of Planned Behaviour, which links attitudes and intentions to actual behaviour; Schwartz's Norm Activation Theory and the Value-Belief-Norm Theory, which explain how personal and moral norms shape pro-environmental actions; Affect-as-Information Theory, which highlights the role of emotions in guiding judgement and decision-making; and Systems Thinking, which frames sustainability as interconnected across social, technical, and cultural domains. Together, these frameworks situate the study at the intersection of technology, behaviour, and cultural practice.

The significance of this research lies in demonstrating the value of employing environmental art to encourage sustainable behaviour among users in buildings equipped with smart automated systems, while also evaluating how audiences are influenced by these interventions. Smart technologies can optimize energy use and performance, but their effectiveness depends on the behaviour of occupants. By embedding building performance data within a digital eco-art installation, this research tests how artistic engagement can serve as a complementary strategy to foster responsibility, awareness, and behavioural change.

The literature review shows that while there have been some efforts to present building-related data to influence occupants, very few have used emotionally engaging environmental art to communicate sustainability concerns. Moreover, within the environmental art field, although the medium aims to encourage environmentally responsible actions, systematic impact assessment, especially quantitative analysis, has been limited. Only a few scholars, notably Curtis (2009, 2011, 2014, 2020), have provided long-term insights into how environmental art influences audiences. Curtis' findings suggest that art can: (1) communicate information in engaging ways, (2) create empathy towards natural spaces, and (3) enhance the attractiveness of sustainability projects for the public. This thesis builds on and extends that body of work by providing new data on how environmental art affects audiences' cognitive and emotional

responses, as well as their intentions to act more sustainably as a result of their interaction with the work.

Environmental psychology and empirical aesthetics further reveal that emotions play a crucial role in decision-making and meaning-making. Affect-as-Information Theory (Clore & Huntsinger, 2007) and the work of Sommer et al. (2019) show that emotional engagement complements cognitive understanding in shaping behaviour. By applying these frameworks, the research not only examines whether audiences understand sustainability messages but also how the emotions elicited by eco-art influence their behavioural intentions.

As part of this study, an innovative digital eco-art installation was developed to represent building performance data in a generative art format. The installation transformed data into a virtual garden of vulnerable wood lilies, where each flower reacted to sustainability performance metrics of specific building zones. Everyday library users could observe fluctuations in colours and forms, linking their own presence and energy use to the well-being of the digital ecosystem. This form of digital eco-art, interactive, data-driven, and situated in a publicly accessible university space, has not previously been investigated in the context of smart buildings.

The installation was designed to elicit both positive and negative emotions, prompting reflection on the consequences of sustainable and unsustainable practices. A questionnaire, inspired by Sommer et al.'s (2019) study, was used to capture the cognitive and emotional aspects of audience experience, alongside intentions for pro-environmental behaviour change. By analyzing these responses, the research advances knowledge in both building sustainability and environmental psychology, while also contributing to the emerging field of eco-visualization within art and design.

Ultimately, this research extends academic understanding by empirically evaluating how data-driven digital eco-art can influence pro-environmental behaviour, while also offering practical insights for architects, planners, environmental educators, and policymakers. At a time when climate change and resource consumption present urgent global challenges, this study demonstrates the potential of data-driven art as an innovative and accessible tool for fostering

environmental awareness, responsibility, and behavioural change within smart building contexts.

0.3 Method

This study follows the Design Science Research Methodology (DSRM) as outlined by Peffers et al. (2007). The research process is structured around six iterative phases: problem identification, objective definition, artifact design and development, demonstration, evaluation, and communication. This approach enables the creation and assessment of an artifact that addresses a real-world problem while contributing to both academic knowledge and professional practice.

0.4 Chapter Outline

This thesis includes four chapters. The Introduction outlines the background and context, provides the purpose of the study and describes the research subject. It has also presented the significance of the research and the methods applied to facilitate the study. As this is a cross-disciplinary study, Chapters 1 and 2 explore literature from the contributing disciplinary fields: art and environmental psychology. Chapter 1 examines the diverse manifestations of environmental art since the 1960s and the paradigm shifts shaped by changing times and artistic movements. It also introduces the new forms of environmental art in the digital age, including installations. Chapter 2 explores behaviour change theories to understand what motivates people to act more environmentally. Chapter 3 focuses on the methods used in this study, while Chapter 4 presents the results of the research, presented in the form of a journal publication. Lastly, the thesis closes with a Conclusion section, which responds to the research questions, outlines the contributions to knowledge, and highlights limitations and directions for future research.

CHAPTER 1

ENVIRONMENTAL ART

This chapter examines environmental art literature to provide a background to its recent manifestations and practitioners' intentions. It outlines some of the many definitions and subcategories of environmental art and explores the changes in the movement through an analysis of books, catalogues, articles, websites and blogs which address this topic. The review also explores the paradigm shifts that have influenced environmental art, and reviews criticisms of the movement and responses to those criticisms.

1.1 Defining environmental art

Thoreau, the famous early American environmentalist and philosopher, wrote as long ago as 1854, in his book *Walden* (Thoreau, 1854, p. 61): *It is something to be able to paint a particular picture, or to carve a statue and so to make a few objects beautiful; but it is far more glorious to carve and paint the very atmosphere and medium through which we look ... To affect the quality of the day, that is the highest of arts.* At its heart, environmental art is an artistic practice that engages directly with lived experience rather than remaining at the level of abstract representation.

Environmental art is an expansive movement that involves an artistic process or artwork where the artist actively engages with the environment. It is a diverse discipline encompassing small personal works, including earth/body art and performance, to permanent, large-scale works (Wildy, 2011). Environmental art is defined as a genre that encompasses works of art directly representing the environment, such as landscape paintings by Constable or Monet, as well as non-representational and performative works that engage actively with the environment and audience (Thornes, 2008). These include art forms like land art, earthworks, site-specific installations, and conceptual works that may not depict the environment directly but evoke ecological themes or foster environmental awareness. The term emphasizes a broad scope that

includes both visual representations and participatory, experiential art forms concerned with environmental issues.

In this context, "environmental art" is a useful general term that refers to any artwork created or exhibited, indoors or outdoors, that addresses environmental issues. Environmental art can be viewed in situ or brought into the gallery as canvases, pictures, sculptures, films, videos, or natural materials such as driftwood, soil, and leaves (Marks, 2015). Numerous artistic movements and art forms from the 20th century, including minimalism, postminimalism, public art, conceptual art, process art, interventions, happenings, the Arte Povera movement, and installation art, are linked to the origins of environmental and land art. Although it is challenging to identify the very first artwork in this category, environmental and land art were clearly recognized as distinct genres by the early 1960s (Jónsson & Sigurjónsdóttir, 2009).

Since the 1960s, environmental art has taken diverse forms, leading scholars to adopt related terms to capture different directions within the movement. 'Environmental art' has often been used interchangeably with 'land art,' 'earth art,' and 'earthworks,' alongside subgenres such as eco-art, eco-ventions, and art in nature (Spaid, 2002; Marks, 2015; Matilsky, 1992; Prigann et al., 2004). Malcolm Andrews, for example, identifies several strands within earth and land art: minimal and ephemeral site interventions (Richard Long, Andy Goldsworthy, Michael Singer); large-scale sculptural earthworks (Michael Heizer, Robert Smithson); gallery installations using landscape materials (Walter De Maria, early Smithson); reclaimed or naturalized industrial sites (Smithson); and conservation-focused works that preserve traditional land uses (Alan Sonfist, Agnes Denes) (Brady, 2007). Building on this, other scholars offer contrasting definitions: Spaid (2002) describes environmental art as any art that 'activates the land,' while Prigann et al. (2004) distinguish between earth art, created in nature with natural materials, and land art, conceived as monumental works that may or may not account for environmental impact (Marks, 2015). This ongoing diversification shows that since the late 1960s, a variety of labels have been applied to nonrepresentational performative environmental art, including land art, earthworks, site-specific art, destination art, ecological art, eco-art, total art, and environmental sculpture. Taken together, this makes the need for a broad new genre to characterize this kind of art perhaps more apparent. According to

Tiberghien (1995), the start of performative environmental art and land art in the 1960s may be linked back to the theoretical debates surrounding abstract expressionism, minimalism, and theatricality. This shift in practice was also reflected in how artists began to relate to landscapes. Traditionally, artists have painted landscapes, but today the connection is reversed: artists now walk out into the landscapes and leave their artwork and signs there (Darabas, 2014).

One pivotal moment in this shift was the Earthworks exhibition. Smithson staged Earthworks, the first significant land and environmental art exhibition, in October 1968. Large outdoor installations created by 14 artists were either photographed or purposefully uncollectible. This stood in stark contrast to the art market's recent commercialization. The title Earthworks was inspired by a science fiction book written by Brian Aldiss about a future America in which even the soil has turned into a valuable resource (Sleeman, 1995). For its time, the show was groundbreaking and altered the notion of what constitutes an artistic creation. The works featured in the exhibition emphasized this new approach to artmaking. This dislocation was amplified by the unconventional nature of the works presented: indoor installations that brought raw earth and debris into the gallery (e.g., Smithson's gravel and mirror pieces, Oldenburg's pile of dug earth), and large-scale outdoor interventions that inscribed or altered the landscape itself (e.g., De Maria's mile-long desert drawing, Oppenheim's crop rings, and Heizer's trenches). These works (Figure 1.1) directly challenged both the conventions of art display and the commodification of art objects (Kastner & Wallis, 1998).



Figure 1.1 Works from the Earthworks exhibition (1968): Claes Oldenburg, *Shovel Piece* (top left); Robert Smithson, *Gravel Mirror with Cracks and Dust* (top right); Walter De Maria, *Mile Long Drawing* (bottom)
 Taken from [nezumi.dumousseaux.free.fr]

Among these, land art, such as Richard Long's *A Line Made by Walking* (1967), can entail small-scale, transient interventions at a location (Figure 1.2). Long aimed to symbolize concepts of place, time, and space by walking a path into a field. He repeatedly walked back and forth in a line across a field until a visible walkway appeared; he didn't use a bulldozer, a spade, or any other tools. All that is left of the piece is a black-and-white photograph documenting the work. This made it clear that an artist can produce art in any setting without the need for specialized equipment, canvas, or traditional artistic skills (Thornes, 2008).



Figure 1.2 Richard Long's *A Line Made by Walking*
Taken from [www.richardlong.org]

Land art can also include natural sculpture on the site. One of the earliest "earthworks" was *Double Negative* (1969-1970) (Figure 1.3). *Double Negative* encourages spectators to think about the relationship between art and the earth by obfuscating the line between sculpture ("art") and everyday things like rocks ("not art"), which is consistent with the goal of modern art. *Double Negative*'s enormous size also prompts reflection on the scope of art and the viewer's relationship to both the earth and the work itself.



Figure 1.3 Michael Heizer, *Double Negative*, 1969-70, Mormon Mesa, Overton, Nevada
Taken from [doublenegative.tarasen.net]

This 1,500 ft. (457.2 m) long and 15 ft. (4.6 m) wide earthwork sculpture was constructed in April 1970 on the northeastern shore of the Great Salt Lake near Rozel Point in Utah entirely of mud, precipitated salt crystals, rocks, and water (Defrančeski, 2022). Constructed from 6,650 tons of rock and earth, the spiral continuously changes form as nature, industry, and time take effect.

Smithson's interest in entropy is demonstrated by *Spiral Jetty*. In this context, entropy is best understood as the change-effect of the matter and shape of land art brought about by the degree of exposure to natural elements (such as wind, rain, snow, drought, and flood). In this way, entropy becomes a crucial component of both aesthetic theory and the evolution of art. In this sense, entropy gives land art a kind of 'life.' Land art, in contrast to typical art approaches, is not hermetically sealed in a museum; rather, it is a part of a particular ecosystem and environment, and as a result of its exposure to natural elements, it evolves, changes, collapses, and disintegrates over time. The physical and biological processes of transformation, regrowth, and decay were emphasized in *Grass Grows*.

This concern with transformation also appears in other works, such as Hans Haacke's *Grass Grows* (1969), which highlighted physical and biological processes of transformation,

regrowth, and decay. On the exposed earth in the exhibition area, Haacke planted and grew green sod. He thought that art was now associated with "mythical time," which distinguished art from actual occurrences.



Figure 1.4 Robert Smithson, *Spiral Jetty*, 1970, Great Salt Lake, Utah
Taken from [holtsmithsonfoundation.org]



Figure 1.5 Hans Haacke, *Grass Grows*, 1969
Taken from [atlasoflandscapesinaroom.com]

1.2 The urgency behind environmental art

The emergence of contemporary non-representational and performative environmental art coincided with the broader environmental awakening of the 1960s. The publication of Rachel Carson's *Silent Spring* (1962) marked a turning point in public awareness, sparking widespread concern about the ecological effects of chemicals like DDT and leading to a 1972 ban on most of its uses in the US. This awakening was echoed in contemporary thought: as cited in Thornes (2008), Pepper (1996, p. 220) summarized the values of the 1960s as an "ecocentric catechism," which included anti-materialism; love and respect for the land; the view of land as one organism; the extension of natural rights beyond humans; the call for an ecological conscience rather than agronomic management; and a plea to return to a holistic, outdoor science of natural history. These ideas not only shaped political discourse but also began to influence artistic practice.

Land art emerged in response to these cultural and environmental shifts. Artists sought to liberate art from conventional gallery and museum settings by creating large-scale, site-specific works in natural, often remote locations. These transient pieces resisted commodification, emphasizing process over permanence (Thornes, 2008). At the same time, growing concerns about environmental fragility, industrialization, and ecological stress inspired works that engaged directly with the landscape, invoked geological history, and expressed a spirituality rooted in nature. Artists used the landscape as a means to test the limits of art and to interact with time, natural forces, and ecological systems, emphasizing the temporality of both art and nature.

Notably, early Land Art was not inherently “eco-friendly” or issue-driven; it was more focused on redefining art’s scope and reimagining our relation to the landscape. Some projects even posed environmental dilemmas. Lintott (2007) questions whether land art is artistically justified and reframes his moral concerns in the context of Tolstoy’s ideas about art. This raises the question of how such works can be justified given ethical concerns that land art may harm nature and incur ecological costs (Brady, 2007). Smithsonian’s *Spiral Jetty* was constructed using heavy earth-moving machinery (dump trucks, front loaders), which has led some critics to question its environmental impact (Rubio, 2012). This ethical tension began to shape a division in practice. By the 1970s, a distinction was emerging between artists treating nature as a neutral canvas and those seeking to work in harmony with the natural environment rather than disrupt it. At the same time, global ecological awareness was intensifying. Eco-art reflected these concerns, with its scales, media, techniques, and themes increasingly tied to escalating environmental problems and humanity’s determined efforts to confront them (Weintraub, 2012).

The term eco-art developed as a branch of the environmental art movement. It is often considered a subgenre, or sometimes an alternative, of environmental art (Marks, 2015). According to Bower (2012), it is “a contemporary art movement which addresses environmental issues and involves collaboration, restoration, and often adopts a more ‘eco-friendly’ approach and methodology.” In her 1992 exhibition *Fragile Ecologies*, curator Barbara Matilsky differentiated ecological art from environmental art, noting that the former

has ethical underpinnings, meaning it seeks not just to represent nature but to heal or change it (Matilsky, 1992). This signalled a shift from visual commentary to active environmental engagement.

Global ecological ideologies are the specific focus of eco-art (Carruthers, 2006), which seeks to stimulate sociocultural change that challenges contemporary individualism and anthropocentric viewpoints and promotes understanding of the inextricable interconnectedness of humans, the environment, and the world (Black et al., 2023). Happenings and community-based performances of the 1960s, such as Joseph Beuys's concept of "social sculpture," exemplified this turn. His *7000 Oaks* project involved citizens in urban reforestation: 7,000 trees were planted around the larger Kassel area, each accompanied by a columnar basalt stone about four feet high (Joseph Beuys Foundation, n.d.). These participatory acts marked a move toward collective, real-world interventions. They fused art with life and politics, creating a paradigm shift that later eco-artists inherited and expanded. Eco-artists also introduced methods such as mapping, walking practices, dialogue-based projects, and tree planting, embedding ecological concerns directly into artistic processes (Black et al., 2023).

Eco-art exhibitions proliferated globally in the 1990s and 2000s, as the social and cultural dimensions of climate change became increasingly central to artistic practice. Linda Weintraub (2012) notes that by the 1990s, "integrated social and ecological approaches" had developed in art, representing an ethical, restorative stance and a departure from the purely formal earthworks of earlier decades. Eco-artists often worked in interdisciplinary teams, collaborating with ecologists, urban planners, and community groups, to create works that could double as ecological research, habitat restoration, or environmental education.

Prominent eco-artists Newton Harrison and Helen Mayer Harrison contend that in order to successfully promote environmental change, environmental art needs to integrate systems thinking (Kastner & Wallis, 1998). Most of their work, such as *Meditations on the Sacramento River, The Delta and Bays* (1976), and *The Lagoon Cycle* (1985), offers comprehensive community solutions to reclaim degraded land and waterways while presenting the harm to entire ecosystems in a collage of media (Marks, 2015). Such projects established a blueprint

for eco-art that is interdisciplinary, solution-focused, and community-rooted. Over the past six decades, eco-art has undergone a significant evolution from traditional gallery-based practices to more expansive modes of art-making in outdoor sites, communities, and digital realms.

Weintraub (2012) also produced a schematic map of artists and different genres of environmental art in her book *To Life*, including performance, bio art, generative art, social practice, digital art, installation, and public art. The following section illustrates how forms of environmental art have evolved, expanding to incorporate environmental issues, new media, formats, and participatory practices. This evolution invites a closer look at the paradigm shifts that have shaped environmental art as we know it today. This chapter examines these paradigm shifts in further detail to define modern environmental art.

1.3 Environmental art paradigm shifts

There have been a few paradigm shifts in the field of environmental art, as listed by Marks (2015):

- The transition of society from prioritizing industrialization to considering environmental problems
- The transition from using natural media in art to employing nature's actual processes to make art
- The change from indoor to outdoor exhibition settings, with a corresponding emphasis on place
- More focus on communal works
- Greater emphasis on participation, process, and social learning in art
- More interdisciplinary collaboration, including between artists and scientists

In the 1960s, land art emerged in response to cultural and environmental factors. Artists sought to free art from conventional gallery and museum settings by situating works directly in nature, often in remote areas. These transient, site-specific works challenged the commodification of art and highlighted environmental fragility, industrialization, and ecological stress. Land art

pushed the boundaries of artistic practice by engaging geological history and spirituality rooted in nature.

Art has historically sparked protest during repression and devotion during spiritual upheaval. In the face of threats such as pollution, climate change, and resource depletion, artists began integrating scientific perspectives into their work to develop environmentally responsive practices and inspire reflection (Weintraub, 2012). Artists like Betsy Damon, known for the *Living Water Garden* (Chengdu, China, 1998), collaborated with engineers and hydrologists to design a park that filters contaminated water using natural processes, educating the public about water ecology. This interdisciplinary approach recalls earlier traditions where figures such as Leonardo da Vinci blurred the line between artistic observation and scientific inquiry (Coles & Pasquier, 2015).

Artists have long depicted social contexts, using creativity to reflect cultural dynamics. As Kinney (2012) notes, the artist's representation of community often mirrors their relationship with culture. John Constable (1776–1837) is regarded as one of the greatest painters of atmospheric phenomena. During his “skying” period (1820–1822), he produced over 100 cloud studies on Hampstead Heath, accompanied by meticulous weather notes (Thornes, 2008). Such practices illustrate how close observation of motion, light, and atmosphere approached scientific inquiry. Similarly, Cézanne's “Mont Sainte-Victoire” or Monet's late series required immersive engagement with place, where the landscape became not only a visual subject but a multisensory environment.



Figure 1.6 John Constable: *Cloud Study*, 1822
Taken from [www.nga.gov/artworks]

Collaboration between artists and scientists has become increasingly recognized. With the headline “Scientists and artists are working together as never before,” *Nature* reported a survey on arts–science collaborations (Black et al., 2023). Both domains employ intuitive and individualized “thinking tools,” suggesting that skills honed in one can enrich the other. This convergence has created fertile ground for deeper collaboration.

One example is Walter De Maria’s *Lightning Field* (1977), a grid of 400 polished steel poles in the New Mexico desert. Although visually simple, its precision required advanced surveying technologies to align geometry with uneven terrain (Weintraub, 2012).



Figure 1.7 De Maria's *Lightning Field* in New Mexico
Taken from [www.diaart.org]

Another example is Michael Pinsky's *Pollution Pods*, which simulate the air quality of major polluted cities. By blending sensory immersion, environmental data, and digital fabrication, these installations represent a newer generation of environmental art (Sommer et al., 2019). This shift from galleries to outdoor spaces also signalled a critique of elitism and commodification in the art world. In environmental art, the site itself often becomes inseparable from the work, such that nature is both medium and context (Carlson, 2000).

When Land Art emerged, it embodied a critique of consumerism and institutional authority by privileging site and process over permanence. Because many earthworks were ephemeral and accessible only through travel or documentation, they reinforced a paradigm where experience outweighed ownership. This anti-commercial stance continues in contemporary digital and participatory eco-art (Root-Bernstein & Root-Bernstein, 2004).

Artists often serve as mediators of complex knowledge: by translating data into tangible experiences, they make abstract phenomena more emotionally resonant (Potter, 2009). For instance, in the *Garden of Sensors*, numerical building performance data was both presented

as technical information and transformed into data-driven art, allowing comparison between cognitive and affective responses.

As Curtis (2011) outlines, artists contribute to taxonomy, anatomy, architecture, design, psychiatry, and material science, reflecting longstanding intersections between art and science. These intersections are increasingly visible in environmental art today, particularly through the use of sensors, data, and visualization to foster ecological awareness and action.

1.3.1 Digital eco-art and eco-visualization

As artists continue to explore how environmental concerns can materialize through creative practice, the concept of aesthetics, traditionally defined as “the study of the mind and emotions in relation to beauty”, is being re-evaluated within environmental art (Weintraub, 2012). Here, aesthetics extends beyond visual pleasure to function as a tool for ecological engagement, ethical reflection, and emotional resonance. In today’s world of information overload, saturated with data and visual stimuli, artists face the challenge of cutting through the noise to create works that captivate, inform, and inspire pro-environmental behavior.

As Weintraub (2011) explains: “Digital art is distinguished by the utilization of digital technologies to create imagery and produce art objects. Digital art is also referred to as computer art, multimedia art, and new media art. Eco artists who produce eco-visualizations frequently rely upon digital technologies.” Such technologies expand the artist’s toolkit by integrating programming, sensors, machine learning, and interactive platforms, directly connecting audiences to the rhythms of environmental systems.

In this context, eco-visualization has emerged as a compelling format for representing environmental data. By bridging abstract information and human emotion through visual metaphors and animated elements, eco-visualizations render complex processes both legible and emotionally impactful. They reposition data not as dry artifacts but as expressive, participatory media capable of fostering awareness and behavior change (Holmes, 2007).

Eco-visualizations also offer scalability. Deployed in homes, airports, or train stations, they embed ecological information into daily life and encourage spontaneous encounters. Unlike site-specific eco-art installations that reclaim a single location, eco-visualizations embrace reproducibility, ubiquity, and interactivity (Holmes, 2007).

A landmark example is *Nuage Vert* by HeHe (Helen Evans and Heiko Hansen) in collaboration with Pixelache (Figure 1.8). This large-scale installation illuminated the emissions of a Helsinki power plant in real time by projecting a green laser outline onto its smoke plume. The outline shifted depending on the community's electricity consumption: the more energy used, the smaller the green cloud became (Pierce et al., 2008). Viewers were encouraged to unplug appliances to enlarge the cloud, transforming a passive viewing experience into an active ecological experiment. The project aimed to raise awareness of energy use, create a dialogue between citizens and infrastructure, and promote ecological responsibility (Holmes, 2011).



Figure 1.8 *Nuage Vert*, light installation visualizing power plant emissions in real time
Taken from Pierce et al. (2008, p.2)

At a more localized scale, *Garden of Sensors*, our case study, can be interpreted as an eco-visualization in a smart-building setting. By translating sensor data into generative visuals, it invites students to reflect on how daily consumption shapes the environment, reinforcing ecological literacy through immersive feedback. This approach parallels Holmes' (2011) eco-

visualization projects, which offered dynamic, building-scale feedback systems to encourage energy-saving practices.

Another notable work is *7000 Oaks and Counting: Real-Time Carbon Loads* by Tiffany Holmes (Figure 1.9). This digital project uses animated trees that correspond to carbon emissions, virtually “planting” trees in relation to real-time energy use (Pierce et al., 2008). By linking data to a familiar organic metaphor, the project enables viewers to grasp the scale of their consumption and cultivates a more immediate sense of ecological responsibility.

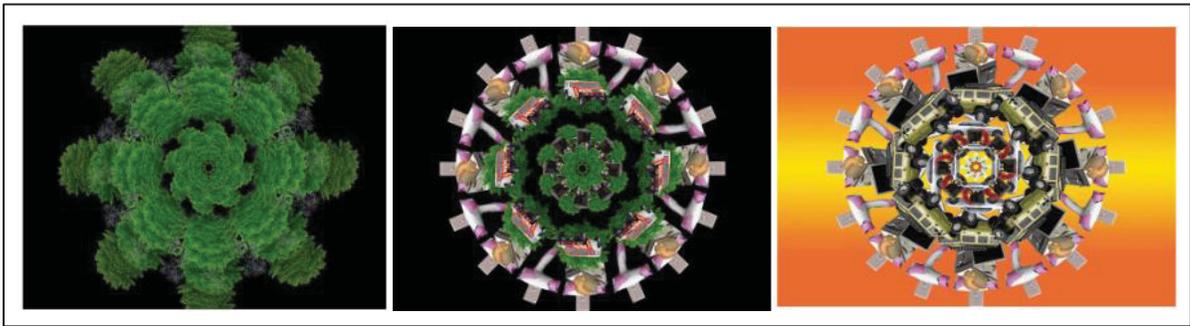


Figure 1.9 Animation still from *7000 Oaks and Counting: Real-Time Carbon Loads*
Taken from Holmes (2007, p.9)

1.3.2 From galleries to grounds: data, community, and generative eco-art

Another key paradigm shift within environmental art was the move from galleries to outdoor settings, responding to consumerism and the commodification of art. This transition was both aesthetic and political, challenging the exclusivity of the “white cube” and emphasizing that environment is not a backdrop but a central part of the message (Marks, 2015). By situating works in public and natural settings, artists underscored the fragility of ecological systems. Ephemeral works, visible only briefly, gained meaning from their disappearance, mirroring ecological impermanence. In this sense, documentation through photographs, videos, or community memory became an integral part of the artwork itself (Kinney, 2012).

Inspired by the civic and environmental activism of the time, artists sought new forms outside commercial galleries to address real-world concerns (Darabas, 2014). This shift reflected a democratization of space: moving from art aimed at cultural elites to art in public spaces that

encouraged interaction across communities (Marks, 2015). The emphasis shifted from private ownership to shared, collective experience. Audience participation became increasingly central. Environmental art evolved into participatory practices where communities were not just viewers but collaborators, acknowledging that lasting impact requires both awareness and agency.

Artists such as Mel Chin, Eve Mosher, and Natalie Jeremijenko brought projects into urban spaces, actively involving local residents. Through workshops, walks, interventions, and public data displays, their work educated, mobilized, and amplified community voices. Natalie Jeremijenko's *OneTrees* (2004) (Figure 1.10), which highlighted the impact of urban micro-environments on genetically identical saplings, making invisible ecological variables visible. Mel Chin's *Revival Field* (1991) (Figure 1.10), a pioneering project using plants to remediate toxic soil, illustrates eco-art's integration of science and ecology. These were not static installations but evolving, responsive processes aimed at raising environmental literacy and influencing behavior.

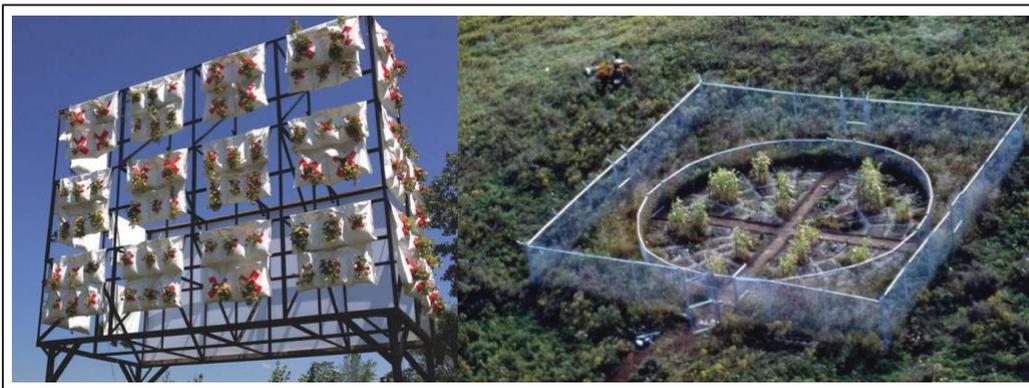


Figure 1.10 Left: Natalie Jeremijenko, *OneTrees* (2004), Right: Mel Chin, *Revival Field* (1991)

Taken from [<https://art21.org/>]

1.3.3 Digital generative art

With the development of digital technologies and new creative tools, approaches to designing images in art have also transformed. Digital platforms open possibilities for focused artistic

interpretations of the world and its values, allowing artists to convey inner perspectives, emotional palettes, and messages more directly (Nataliia et al., 2022). Bramantyo Dupui (2021) examines how specialized digital technologies can be applied to the challenge of creating meaningful images, arguing that each art form seeks to convey a message shaped by the artist's intent. In this sense, digital art becomes a medium for precision in expressing viewpoints and addressing problems.

While digital tools and computer graphics make the artist's message visually accessible, they may neglect a human-centred perspective. This critique highlights a tension: digital art's realism can enhance sensory connection, yet its immersion in the information environment may reduce space for analytical thought (Nataliia et al., 2022). As a distinct layer of contemporary practice, digital generative art blurs illusion and reality, reinforcing nonverbal cues and shaping perception through visual, auditory, and emotional engagement. By immersing audiences in the informational space of artistic visuals, it connects them to the consciousness of a digital society, reshaping how the world is perceived.

Generative digital art emerged as soon as computers became available. Algorithmic works were produced in the 1960s by artists such as Frieder Nake and Vera Molnar, though these early pieces did not employ methods associated with artificial intelligence (Mendelowitz, 2020). A landmark development came with Harold Cohen's AARON, initiated in 1973 and refined for over forty years, which used an expert system to generate rule-based drawings and paintings (Cohen, 2016; Mendelowitz, 2020). Rather than producing random shapes, AARON encoded knowledge to create coherent visual forms that evolved. Generative art is often structured around inputs and outputs, such as pseudorandom numbers producing geometric drawings or musical data generating animations. In some cases, outputs are fed back into the system, creating feedback loops associated with cybernetics' "circular causality." This process underscores the collaborative role of the artist, who sets initial conditions and adapts to machine-produced results. Cybernetics provided a vocabulary for feedback, communication, control, and self-organization that proved influential across both computing and the arts (Ilfeld, 2012; Goodchild, 2021). As Weintraub (2012) explains, generative art is a process-based form that employs dynamic, semi-autonomous systems capable of real-time change. Its

unpredictability and open-endedness create a continual interplay between human invention and machine autonomy (Soddu, 2008).

Generative art aligns with eco-art when it employs living systems, digital media, or technological interventions that echo ecological processes or emphasize sustainability. Principles such as self-organization, emergence, and feedback parallel the behavior of ecosystems. Nature itself can be seen as a generative system, constantly evolving in response to internal and external conditions. Eco-generative art emerges at this intersection, using algorithmic systems to reflect environmental data, simulate biological growth, or foster interaction with natural processes. The work of Carl Cheng illustrates this fusion (Figure 1.11). His *Erosion Machine* and later projects embedded environmental processes into automated cycles and audience-responsive mechanisms. By foregrounding time, entropy, and feedback, Cheng's machines connected generative systems to ecological thought and natural dynamics (Damman, 2022).



Figure 1.11 *Erosion Machine*, Carl Cheng
Taken from Damman (2022, p.9)

The uncertainty inherent in artificial projects offers opportunities to make decisions that shape identity and recognition. This complexity resembles that of natural systems. Soddu (2008) notes that the harmony of natural-like complexity recalls Renaissance humanism, where man, geometry, and nature were unified as conscious reasoning rather than individual caprice. Generative approaches similarly produce digital artifacts that reflect this harmony, showing that such systems are not only aesthetic tools but also conceptual models for simulating nonlinear, self-organizing patterns in nature.

In the digital and data era, the ways we make art, tell stories, and visualize the natural world have transformed (FitzGerald, 2020). While information sharing through new media is central, the abundance of digital content raises concerns about accuracy. Information overload can cause skepticism toward content, or at best, confusion about reliability (Weintraub, 2012). Data-driven eco-art responds to this by making invisible or inaccessible environmental information visible and meaningful across different contexts.

One example is Amy Franceschini's *Victory Gardens+* (2006-2007) and *Victory Garden Seed Library* (2008-present). While they appear to be grassroots farming initiatives, they also function as conceptual art (Nesbit, 2009). The projects included databases and online interfaces that tracked participation, planting, and harvest yields, transforming geographic data into visual maps and iconography that symbolized garden sites (Weintraub, 2012). In such works, the artist shifts from sole creator to systems designer, constructing rules and conditions for unfolding environmental expression. What once seemed like tools that might hinder creativity now expand it, enabling direct engagement with codes of harmony. This synthesis between art and science opens new fields of practice and deepens our understanding of creativity as a collaborative process between human intention and computational systems.

This generative structure mirrors the decentralized, evolving, and co-created logic of ecosystems, making it uniquely powerful in environmental contexts. Although the mediatized character of computer-generated art initially clashed with traditional notions of natural aesthetics, recent reappraisals emphasize that mediated processes shape not only how we experience art but also how we conceptualize nature itself (FitzGerald, 2020).

David Suzuki observes that because we no longer “see ourselves as physically and spiritually connected to family, clan, or land,” we live “chiefly by the mind” and remain disconnected from the natural world (Coles & Pasquier, 2015). In his afterword, Ivakhiv (2013) highlights digital technology as a novel form of image/world processing. He argues that the moving image not only depicts and captures the world but simultaneously constructs its own universe, embedding viewers in complex relationships. With interactive media, the viewing experience

can be reorganized in real time, enabling a new kind of world-making within the broader category of the moving image.

Many perceive technology as incompatible with nature, reinforcing the idea that it has estranged us from the natural realm (Beery et al., 2023). Yet digital technologies can also serve as tools of reconnection, uniquely suited to exploring new forms of ecological engagement. Weintraub (2012) describes such practices as “utilitarian,” emphasizing adaptive methods of cultural production that address deficits of the present. Contemporary environmental artists often adopt inter- and transdisciplinary approaches to raise awareness of sustainability and to envision more compatible futures for humans, other species, and ecological systems (Darabas, 2014). As Soddu (2008) notes, design in technological domains such as artificial life and artificial intelligence often returns to natural principles, rediscovering the processes and patterns of nature through nonlinear dynamics and feedback.

Taken together, these paradigm shifts show how the digital and information age has transformed artistic expression. Data-driven eco-art continues to make invisible or inaccessible environmental information perceptible across different contexts. Through installations, performances, and interactive media, artists not only communicate data but also open imaginative pathways toward reconnection with ecological systems.

1.3.4 The evolution of AI art and generative eco-visualization

AI-based art production began in the 1970s, expanded in the 1990s, and has recently experienced a surge of renewed interest (Mendelowitz, 2020). This trajectory reflects how advances in technology consistently drive new forms of creative expression. As technology evolves, artistic imagination continually adapts, responding not only to current possibilities but to emerging horizons. The Dartmouth Workshop of 1956, where the term artificial intelligence was coined, defined the field broadly as “making a machine behave in ways that would be called intelligent if a human were so behaving” (Mendelowitz, 2020). This foundational description opened the door to diverse interpretations, influencing both scientific research and artistic experimentation.

By the late 1980s, artists increasingly treated computers not merely as tools but as media in their own right, shifting from traditional techniques to digital experimentation. This evolution set the stage for interactive AI works such as Memo Akten's *Learning to See* (2017) and Mario Klingemann's *Uncanny Mirror* (2018) (Canet Sola & Guljajeva, 2024). Both projects employed generative neural networks with live camera input, creating closed-circuit video systems in which real-time data streams interacted with machine-learning outputs. These works demonstrated how AI could generate dynamic, responsive environments, hinting at the vast potential of computer vision and generative AI for art (Cao et al., 2023).

The rise of AI art has prompted debate. Manovich (2019) questions whether "AI art" should be distinguished from other digital art merely because AI techniques are used. He argues that artistic control generally remains with the human creator, positioning AI as an instrument rather than an autonomous author. This distinction underscores that while AI can replicate logical processes, the origination of ideas remains human-driven. As Soddu (2008) observes, generative software embodies "artificial life" by enacting procedural logics defined in advance but producing different results each time. Beginning from varied inputs and requests, such systems always culminate in distinct outcomes that nonetheless represent the same underlying Idea. This flexibility emphasizes the procedural and emergent qualities of generative systems, aligning them with ecological processes and reinforcing their relevance for eco-visualization.

Mendelowitz (2020) classified AI artworks into five categories, generative, reactive, interactive, learning, and static, based on their operational principles. These metrics consider aspects such as introspection, perception, actuation, and self-mutability. Among these, generative and interactive approaches are the most prevalent in contemporary AI art (Olgen & Cucuzzella, 2024). This framework helps contextualize the diverse roles AI can assume in artistic practice, from static repetition to dynamic engagement.

Refik Anadol similarly employs generative principles in his large-scale "data sculptures." By transforming massive datasets into three-dimensional, immersive visualizations through machine learning and AI, he demonstrates how data can be experienced as spatial, emotional, and aesthetic phenomena (Simonite, 2020). Within this taxonomy, the project *Garden of*

Sensors occupies a distinctive position. While conceptually linked to interactive eco-art, its system behavior aligns with the generative category. It translates historical building data into symbolic visual states, represented as the health of digital flowers. Such works, which rely on internal processes rather than external input, exemplify generative systems based on introspection.

In contrast, interactive eco-art projects engage participants directly in shaping the artwork. A notable example is *Visions of Destruction*, which uses eye-tracking sensors to transform viewers from passive observers into agents of landscape change (Canet Sola & Guljajeva, 2024). As gaze points trigger the progressive degradation of digital environments, the work creates a symbolic link between human attention and ecological consequence, evoking responsibility for environmental collapse. Generative AI highlights the fluidity and procedural qualities of contemporary art, capturing the evolving nature of cultural expression derived from learned data. Artists must design interfaces that guide audiences through algorithmic latent spaces while preserving meaningful human control. In this role, artists act as navigators and translators between invisible computational processes and visible cultural meaning (Santoni de Sio & van den Hoven, 2018; Canet Sola & Guljajeva, 2024).



Figure 1.12 Visions of Destruction
Taken from Canet Sola & Guljajeva (2024, p.3)

1.4 AI and nature

The paradox of using digital systems to reconnect with nature lies at the heart of generative environmental art, challenging the traditional binary between technology and ecology. Rather than distancing us from the natural world, digital tools are increasingly employed to interpret, represent, and even restore it. Louv, author of *The Nature Principle*, writes: “The future will belong to the nature-smart, those individuals, families, businesses and political leaders who develop a deeper understanding of the transformative power of the natural world and who balance the virtual with the real. The more high-tech we become, the more nature we need” (as cited in Coles & Pasquier, 2015, p. 6). This perspective underscores the urgency of directing technological progress toward ecological connection rather than distraction.

Bio-inspired AI artworks exemplify the fusion of AI with ecological imagination, forming pioneering examples of environmental AI art (Olgen & Cucuzzella, 2024). These works challenge conventional views of artificial systems by modelling them on organic forms and

processes. In the media installation *Perception of Perfection*, Süleyman Yılmaz (2023) reflects: “The question is what is perfection? Does it really exist, somewhere outside of our imagination? Why are we constantly attempting to transform nature with our own obsessive perception of perfection? Isn’t it perfect enough?” Such questioning illustrates how bio-inspired art encourages audiences to reconsider assumptions about aesthetics, control, and our relationship with the natural world.

Another example is *Fish to Robot*, which stages a live dialogue between biological signals and machine intelligence. The electrical pulses of a fish, clicks and pauses resembling binary code, are detected by the DharmAi AI system. The robot processes these signals, generating new patterns and densities that are translated into sound. Humans can hear the fish’s signals in real time, producing a generative soundscape that merges organic communication with artificial processing (Weintraub, 2012). By extending sensory boundaries through mediated yet intimate exchanges, such works open new ways of experiencing the environment.

CHAPTER 2

PRO-ENVIRONMENTAL BEHAVIOR AND BEHAVIOR CHANGE

To understand users' sustainable behavior in the built environment, we first define pro-environmental behavior (PEB). Environmental psychology highlights the emotional, cognitive, and contextual factors that shape how occupants think, feel, and act. This chapter reviews key theories of PEB, strategies for encouraging it, and the psychological and emotional mechanisms through which environmental art can influence awareness and action.

2.1 Pro-environmental Behavior and Behavior Change Theories

PEB has been studied extensively since the 1970s (Ajzen, 1991; Allen & Ferrand, 1999; Cialdini, 2003; Schwartz, 1977; Stern, 2000). Research consistently shows that both internal factors (values, beliefs, emotions) and external factors (social norms, infrastructure) shape environmentally responsible action. Over time, multiple models have been developed to explain these dynamics.

This project emphasizes mechanisms most relevant to environmental-art interventions. Foundational contributions by Cialdini (2003) and Allen & Ferrand (1999) established frameworks for behavior change, and later work, including that of Curtis, applied these ideas within artistic contexts. Since our goal is to evaluate whether the installation influences behavioral change, we examine both internal states (emotion, cognition) and the external experience created by the installation. In this context, we define PEB as behavior aimed at minimizing negative impacts on the natural or built environment (Kollmuss & Agyeman, 2002). Given its multiple determinants, PEB must be analyzed from different perspectives. Historically, it was assumed that information and awareness drive PEB. However, evidence shows that knowledge alone rarely results in behavior change (Kollmuss & Agyeman, 2002). For this reason, we introduce key psychological theories in the following sections to better explain the mechanisms that drive pro-environmental behavior.

2.2 Theory of Planned Behavior

A central factor in the Theory of Planned Behavior (TPB) is the individual's intention to perform an action, which reflects the motivational factors underlying behavior (Ajzen, 1991). Ajzen's TPB is widely recognized as a foundational framework in research on pro-environmental behavior (Bamberg & Moser, 2007; Jackson, 2005; Kollmuss & Agyeman, 2002; Stern, 2000) and is frequently cited as the leading social-psychological model of attitude and behavior (Jackson, 2005). According to the model (Figure 2.1), a person's intention to engage in a behavior is influenced by three main factors: (1) personal attitude toward the behavior, (2) subjective norms, meaning the perceived social pressure from close others and whether they would approve or disapprove (Ajzen & Fishbein, 1980; Jackson, 2005), and (3) perceived behavioral control, or the individual's belief in their ability to carry out the behavior (Ajzen, 1991). This last component highlights that individuals who believe they can accomplish a task are more likely to follow through, making it particularly relevant for behavior-change interventions.

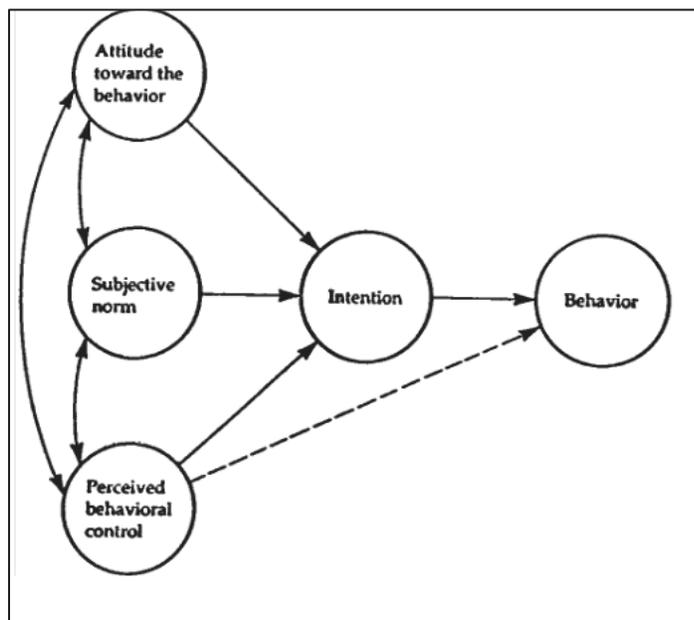


Figure 2.1 Theory of Planned Behaviour
Taken from Ajzen (1991, p182)

Many studies in environmental psychology fail to find strong correlations between attitudes and behaviors. One reason is mismatched measurement scopes, where attitudinal items are general (e.g. “I care about the environment”) yet behavioral items are narrow and concrete (e.g. “I reused my water bottle yesterday”) (Wintschnig, 2021; Kaiser, 2005). According to the compatibility principle, correlations strengthen when attitudes and behaviors are measured at the same level of specificity (Johnson, 2009; Kaiser, 2005). Theories such as TPB address this by insisting that attitudes be directly tied to the specific behavior under study (Ajzen, 1991). When this alignment is lacking, observed correlations are weak or misleading (Vieira et al., 2023). Narrowing measurement focus often improves predictive accuracy, albeit at the cost of broader generalizability (Essiz & Senyuz, 2024).

Although several models have followed TPB, the link between attitude and intention remains weak, as does the assumption that people consistently think rationally (Kollmuss & Agyeman, 2002). While TPB has been instrumental in explaining the psychological determinants of pro-environmental behavior, it primarily relies on self-reported attitudes and perceived control, often considered in isolation from the immediate physical or sensory context in which behaviors occur.

2.3 Norm Activation Model

To address limitations of earlier models that explained pro-social behavior mainly through external pressures, researchers have emphasized the internal moral processes that motivate altruistic action, even when such actions involve personal costs and lack external rewards. Pro-social behavior frameworks include moral emotions, intrinsic motivations, and non-calculated actions. Eisenberg and Miller (1987) define pro-social behavior as voluntary and deliberate actions intended to benefit another person, with the motivation behind the behavior left unspecified. Motives may be positive, negative, or mixed (Kollmuss & Agyeman, 2002). A positive motivation might be empathy, compassion, or a genuine desire to help. A negative motivation could be guilt, social pressure, obligation, or even a desire to avoid punishment.

Schwartz (1977) developed the Norm Activation Model (NAM), which posits that pro-social behavior is driven by the activation of personal moral norms, internalized feelings of moral obligation. These norms are activated when an individual becomes aware of the negative consequences of not acting (awareness of consequences) and feels personally responsible for those consequences (ascription of responsibility). Once these conditions are met, the activated personal norm can lead to altruistic behavior (Blamey, 1998) (Figure 2.2).

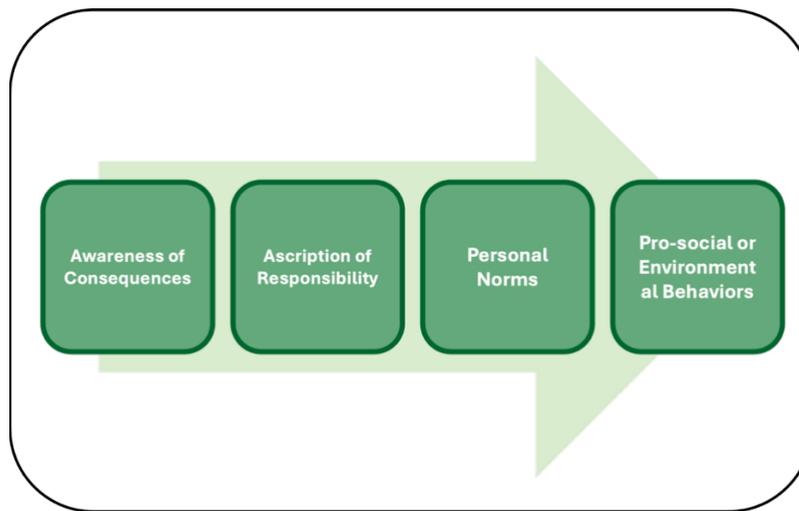


Figure 2.2 The Norm Activation Model (NAM)
Adapted from Schwartz (1977) and De Groot & Steg (2009)

Individuals must first become aware of a need, recognize the consequences of inaction, and believe they are capable of helping. These steps activate a sense of moral obligation, which then motivates behavior (de Groot & Steg, 2010; Schwartz, 1977). However, before acting, people often evaluate anticipated costs and benefits, which can lead to hesitation or defensive denial, a refusal to accept responsibility or exaggeration of barriers (Harland et al., 2007). In such cases, the personal norm remains inactive, and the individual retreats without action (Schwartz, 1977). The Norm Activation Model is useful for showing why moral concern alone does not always translate into behavior, highlighting the need to design experiences that foster early awareness and minimize psychological exit points (Onwezen et al., 2013; de Groot & Steg, 2010). However, NAM has limitations: it focuses primarily on moral obligation and does not fully account for broader value orientations, affective processes, or contextual influences

that also shape behavior. These gaps motivated subsequent frameworks, such as the Value-Belief-Norm theory and Affect-as-Information, which extend NAM by integrating values, emotions, and situational context.

2.4 Value-Belief-Norm Theory

Paul C. Stern and colleagues (1999) developed the Value-Belief-Norm (VBN) theory to explain the psychological processes that lead individuals to engage in pro-environmental behaviors. Building on Schwartz's Norm Activation Model (NAM), the VBN framework integrates personal values, environmental beliefs, and perceived norms to predict environmentally significant actions (Fig. 2.3).

The VBN theory presents a causal chain in which individual values and beliefs shape pro-environmental behavior. Three value orientations are central: a social (altruistic) orientation, focused on reducing the suffering of others; an egoistic orientation, centered on avoiding harm or discomfort to oneself; and a biospheric orientation, concerned with protecting the non-human natural world (Stern et al., 1999). All individuals hold these orientations to varying degrees. For example, a deep ecologist may strongly prioritize the biospheric orientation, while a physician may emphasize the altruistic orientation. Empirical studies (e.g. de Groot & Steg, 2007; de Groot & Steg, 2008) support the validity of this three-way value distinction and demonstrate how value orientations relate to awareness of environmental consequences and personal norms.

These values influence environmental beliefs, including an ecological worldview (as measured by the New Environmental Paradigm), awareness of environmental consequences (AC), and the ascription of personal responsibility (AR) for addressing those consequences. When activated, these beliefs trigger personal norms, internalized moral obligations, that ultimately guide environmentally significant actions such as conserving energy, recycling, or supporting environmental policies (Stern et al., 1999).

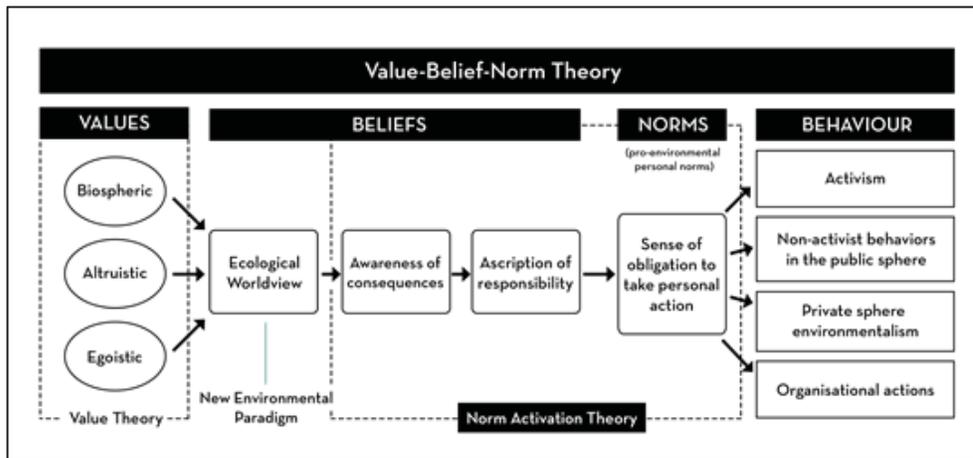


Figure 2.3 The Value-Belief-Norm Theory
 Taken from Horn & Wehrmeyer (2020, p.40)

Awareness of consequences (AC) and ascription of responsibility (AR) are cognitive processes involving moral and causal reasoning. AC arises when an individual recognizes that certain behaviors, or lack of action, may harm others, society, or the environment (Schwartz, 1977). This mental shift reflects deeper moral engagement, where facts are evaluated for both accuracy and ethical significance. AR, by contrast, engages a person's sense of agency: the process of linking one's own actions or inactions to harmful outcomes (Stern et al., 1999). It requires not only recognizing consequences but also internalizing accountability. This shift is especially critical when individuals might otherwise feel disconnected from large-scale environmental issues.

Curtis et al. (2014) published an overview of their studies and major findings. Drawing on research about values, beliefs, and attitudes (Stern et al., 1999; Triandis, 1979), Curtis argued that since these variables influence pro-environmental behavior (Kollmuss & Agyeman, 2002), and the arts have been shown to impact these same variables (Belfiore & Bennett, 2006), art can function as a driver for environmentally friendly behavior. Curtis further proposed that art also shapes awareness of consequences, environmental self-identity, habit, and social norms. However, cognitive recognition alone does not guarantee action. Curtis et al. (2014) emphasize that art influences not only values and beliefs but also evokes powerful emotional responses, which in turn shape self-identity and social norms. Such findings highlight that emotional

engagement often determines whether consequences feel urgent and whether responsibility is experienced as personally binding. In this way, affect is not merely an accompaniment to cognition but a source of information that guides how norms are activated and acted upon. This recognition underscores the necessity of studying Affect-as-Information Theory, which provides a framework for understanding how emotions function as signals that transform abstract awareness into concrete motivation for pro-environmental behavior.

2.5 Affect-As-Information

Affective processes shape how cognitive evaluations are experienced and prioritized. As Clore and Huntsinger (2007) explain, knowing and feeling are intertwined; emotions do not merely accompany judgment but serve as information that assigns value to thoughts, behaviors, or environmental cues. Feelings of concern, guilt, or sadness in response to environmental issues can signal moral significance, reinforcing or even initiating the sense of responsibility central to AR. Such emotional cues can catalyze the move from intention to action.

People often interpret how they feel as a cue for evaluating situations, thoughts, or actions (Clore & Huntsinger, 2007). For example, positive affect may signal that something is valuable or going well, while negative affect may suggest problems or the need to reconsider. This emotional feedback influences not only what people think but also how they think, shaping whether they adopt a broad relational (global) processing style or a narrow detail-focused (local) style (Gasper & Clore, 2002; Clore et al., 2001). Because affect and cognition are intertwined, affect plays a central role in assessing responsibility, risk, and moral relevance (Clore & Huntsinger, 2007). In environmental design or artistic installations, evoking the right emotional tone can significantly influence the effectiveness of the message.

Clore and Huntsinger (2007) provide compelling demonstrations of how emotions shape judgment. For instance, in a classic study, respondents rated their life satisfaction lower on rainy days; however, when reminded that their mood might be weather-related, the effect disappeared, showing that feelings guide judgment unless their source is clarified (Schwarz & Clore, 198). In a similar experiment, jurors who felt upset about a corporate bankruptcy were

more likely to blame someone, unless they realized their anxiety came from being in the juror role, not from the case itself (Kadous, 2001, as cited in Clore & Huntsinger, 2007). Research after the September 11 attacks further showed that different emotions of the same valence can produce divergent outcomes: anger increased support for retaliatory policies, whereas fear heightened risk perception, even in unrelated domains (Lerner et al., 2003). Other studies demonstrate the role of disgust in moral judgment; participants placed in dirty environments judged morally ambiguous actions more harshly, but only if they were highly attuned to bodily sensations (Schnall et al., unpublished, reported in Clore & Huntsinger, 2007). Together, these findings illustrate that emotions are not background noise but act as information signals, guiding evaluations depending on how they are interpreted and attributed.

Affect-as-Information can be seen as a mechanism that enhances personal norm activation within the VBN framework by helping individuals interpret emotional responses as meaningful input. Han et al. (2017) have shown that extending the Value-Belief-Norm model to include emotions provides a stronger account of pro-environmental decisions, supporting the idea that affective signals shape the activation of personal norms. This is especially relevant in immersive, affect-rich contexts such as interactive art, where emotional engagement can substitute for or reinforce cognitive processing. Research on environmental art demonstrates that aesthetic experiences can elicit strong emotional reactions and increase engagement with sustainability issues (Kaufmann et al., 2023; Nummenmaa & Hari, 2023). By intentionally blurring the boundary between feeling and knowing, these environments create fertile ground for activating moral norms and motivating pro-environmental behavior. Such findings align with studies on art and emotion showing that affective responses to artworks function as informational cues that guide judgment and action (Clore & Huntsinger, 2007; Gerger et al., 2014).

2.6 Emotional processes in environmental art

Emotion research highlights that affective responses are multi-component processes. According to Frijda & Mesquita (1998), emotions arise from an antecedent event, followed by appraisal of its relevance, and lead to affective experience, arousal, and action readiness

(Figure 2.4). These components may then influence expression, other behaviors, or belief change, while also feeding into processes of significance and regulation.

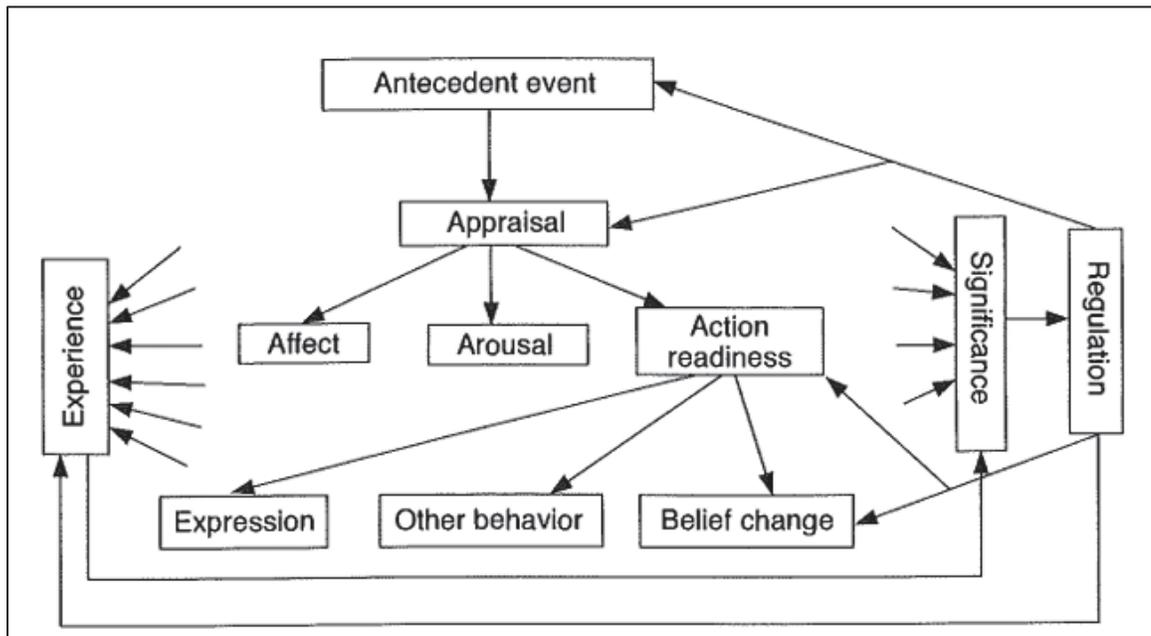


Figure 2.4 The emotion process
Taken from Frijda & Mesquita (1998, p.276)

In the context of environmental art, the antecedent event is the encounter with the artwork, the appraisal involves interpreting its environmental meaning, and the resulting affective and arousal responses may trigger reflection or readiness to act. This broader framework helps situate the role of emotions in connecting aesthetic experiences with pro-environmental behavior.

People's reactions to environmental issues are greatly influenced by their emotions, which may motivate them to action, take time to reflect, or shut down and withdraw entirely. Emotions are mechanisms that give environmental messages urgency and relevance; they are not merely informational byproducts but central mechanisms in environmental psychology and climate communication (Wilson & Arvai, 2006). However, it is still difficult to distinguish between the emotions that support and undermine pro-environmental behavior. Although in this study

emotions were measured in terms of positive and negative affect, the literature distinguishes several groups of emotions that play distinct roles in pro-environmental behavior.

Self-conscious emotions such as guilt, shame, and pride are tied to moral norms and responsibility; they have been shown to influence whether individuals feel obligated to act sustainably (Onwezen et al., 2013; Bissing-Olson et al., 2016). However, depending on the situation and framing, the same emotion can produce quite different results. For example, when it comes to particular behaviors that people think they can modify, guilt has often been associated with reparative behavior. Guilt, whether individual or group, can be a strong motivator when people acknowledge their role in environmental damage. However, guilt may cause defensiveness, resistance, or backlash rather than engagement if it is interpreted as accusatory or manipulative (Swim & Bloodhart, 2015). This is particularly true when guilt is presented in a way that makes people feel ashamed, which is a self-conscious feeling associated with stable characteristics rather than actions. Shame is often counterproductive because it tends to encourage withdrawal and the idea that change is impossible (Tangney et al., 2007).

Other-oriented emotions such as empathy, compassion, and sympathy support altruistic and biospheric values, strengthening concern for the environment and motivating prosocial action (Berenguer, 2007). In the context of environmental art, these emotions are central to how aesthetic experiences foster connection and moral engagement. Curtis (2009, 2010, 2011, 2014) consistently emphasizes that art can evoke empathy and emotional affinity toward the natural world, enabling audiences to feel rather than simply understand environmental issues. Such affective engagement helps individuals perceive the environment as part of their social and moral sphere rather than an external system.

Curtis (2014) expands on the model originally proposed by Kals et al. (1999) to illustrate the emotional and cognitive mechanisms through which the arts can influence environmental behavior. As shown in Figure 2.5, the model highlights three key affective pathways: emotional affinity with nature, cognitive interest in nature, and emotional indignation about insufficient environmental protection. While Kals et al. (1999) emphasized direct experiences

of nature as primary sources of emotional affinity, Curtis's adaptation demonstrates that artistic experiences can similarly cultivate empathy and attachment toward nature, stimulate intellectual curiosity, and evoke moral emotions such as concern or outrage. Through these pathways, art contributes to shaping environmental attitudes and promoting pro-environmental action.

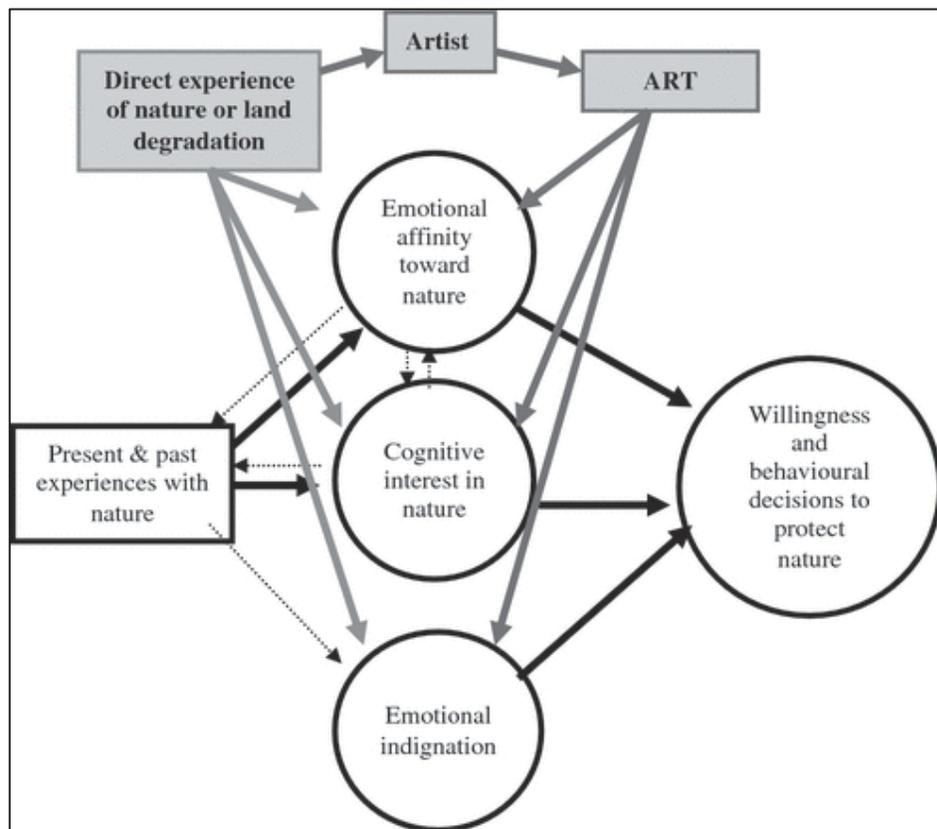


Figure 2.5 Model illustrating how the arts affect environmental behavior by increasing emotional affinity toward nature
Taken from Curtis (2014, p.182)

Empathy consistently demonstrates the ability to promote environmental concern and action. Unlike pity, empathy is congruent with the perceived welfare of someone else, involving feelings like sympathy, compassion, and tenderness (Batson & Ahmad, 2009). This could include empathy for future generations, vulnerable communities, or even nonhuman life impacted by ecological disruption in climate change communication. Deeper emotional

connection and moral responsibility are typically evoked when the message asks viewers to adopt an empathic viewpoint rather than staying detached or critical.

Beyond these, discrete positive emotions such as hope, awe, and joy can broaden perspective, encourage reflection, and sustain long-term engagement with environmental issues (Ojala, 2012; Keltner & Haidt, 2003). Hope has been identified as a particularly constructive emotion in climate communication, helping individuals remain motivated despite the scale of the problem (Ojala, 2012). Similarly, awe and wonder, often evoked by art or nature, can expand cognitive focus and foster a sense of connection to something larger than oneself, reinforcing biospheric values and a willingness to act (Keltner & Haidt, 2003; Sommer & Klöckner, 2021).

According to Keltner and Haidt (2003), awe arises when we encounter something perceptually or conceptually vast that cannot be easily assimilated into our existing mental schemas. In other words, awe forces a temporary suspension of familiar frameworks, prompting the mind to reorganize and create new ways of making sense of the world. When an experience deviates from how we typically perceive the world, it triggers a “need for accommodation.” A stimulus that surpasses our expectations may prompt us to update mental models to make sense of the experience. In empirical investigations, Shiota et al. (2007) found that participants’ awe narratives often involved nature, art, or music, and reported feelings of self-diminishment and increased connectedness, key features of the small-self perspective. Additionally, in the theoretical framing of awe as a meaning-making emotion, researchers argue that when core meaning systems are challenged, awe pushes individuals to reconsider and potentially revise their beliefs (Ihm et al., 2019).

On the other hand, negative emotions such as fear, anger, and sadness can heighten urgency and moral engagement, yet may also provoke defensive denial, apathy, or emotional fatigue if not coupled with a sense of efficacy or constructive framing (Markowitz & Shariff, 2012; Brosch, 2021). These emotions are often central in environmental communication because they make threats feel immediate and morally charged; however, when audiences are overwhelmed or feel powerless, negative affect can suppress engagement rather than motivate it (O’Neill & Day, 2009). Fear, for instance, can prompt attention and risk perception but may also induce

avoidance if individuals lack clear avenues for action. Anger may drive collective mobilization when attributed to systemic injustice or negligence, but can backfire when directed inward as guilt or helplessness. Sadness and grief over environmental loss, sometimes termed eco-grief or solastalgia, can likewise foster reflection and empathy when coupled with collective meaning-making (Cunsolo & Ellis, 2018).

These distinctions highlight that emotions are not defined merely by their valence but by the specific ways they shape meaning-making, moral reasoning, and behavioral intention. To better understand how these emotional mechanisms operate in practice, the following section examines selected examples of environmental art projects that intentionally evoke different emotional responses to stimulate reflection, empathy, and behavioral engagement.

2.6.1 Emotions in practice: examples from environmental art

Environmental art is especially powerful in its capacity to evoke emotions that transform abstract information into felt experience. Immersive installations, such as *Pollution Pods* (Sommer et al., 2019), demonstrate how emotions like empathy, discomfort, or awe can make environmental issues tangible and morally urgent. Self-conscious or other-oriented emotions tie personal accountability to moral concern (Curtis, 2014; Berenguer, 2007; Ojala, 2012). In this way, art serves not only as an aesthetic encounter but also as an affective catalyst for pro-environmental reflection and action.

Swim and Bloodhart (2015), for instance, showed that participants' emotional reactions, such as guilt, sadness, and worry, were more intense when they were shown polar bear imagery in an empathic framing. These emotional reactions were strongly correlated with increased support for pro-environmental activities and climate activism. The writers examined three types of emotions: future-oriented ones like worry and hope; disengaging ones like boredom, moral ones like guilt, shame, empathy, and pride. Especially, participants discovered that although worry helped them realize the seriousness of climate hazards, hope gave them the optimism that something could still be done. It was discovered that maintaining engagement over time required this emotional pairing. When connected to prior environmental actions,

pride was observed as a positive emotion. Boredom, on the other hand, was linked to lower engagement and reflected detachment since it indicated that the viewer saw no opportunity for participation or relevance.

The study found that artworks capable of activating both strong negative and positive emotions were more likely to promote reflection, awareness, and support for climate-related action. Importantly, these artworks were not only visually striking but also contextually rich, allowing viewers to feel both overwhelmed by the problem and motivated by a sense of possible agency. In this sense, Sommer and Klöckner (2021) extended this emotional focus into the field of aesthetics and climate art. In their analysis of audience reactions to climate-related artworks presented at the ArtCOP21 global festival, they aimed to connect emotional and cognitive responses through a cluster analysis. Their study drew from both environmental psychology and the psychology of aesthetics to examine how visual artworks could act as emotional triggers. Inspired by Weber's (2006) observation that a weak emotional connection is one reason for low climate action, they categorized audience responses across a wide range of feelings. These included positive emotions like happiness, hope, awe, surprise, and inspiration, and negative emotions such as guilt, sadness, helplessness, anger, and anxiety.

For the current case study, *Garden of Sensors*, a mix of emotions discussed in this chapter was integrated into the artwork's design and evaluation framework. Table 2.1 summarizes the key emotions explored, their theoretical sources, and how they were operationalized within the context of the installation.

Table 2.1 Emotions discussed in this chapter, their functions in environmental art, and theoretical sources

Emotion type	Example emotions	Main psychological function	Role in environmental art	Key references
Self-conscious emotions	Guilt, pride, shame	Regulate moral norms and personal responsibility; influence intention through norm activation	Art can evoke awareness of personal contribution to environmental issues (guilt) or encourage pride in sustainable values	Onwezen et al. (2013); Bissing-Olson et al. (2016); Curtis (2014)
Other-oriented emotions	Empathy, compassion, sympathy	Strengthen altruistic and biospheric values; promote prosocial action	Immersive and narrative artworks foster empathy and moral concern toward people, animals, or ecosystems	Berenguer (2007); Severson & Kahn (2010); Curtis (2009, 2014); Sommer et al. (2019); Kaufmann et al. (2023); Klöckner et al. (2021)
Positive affect	Hope, awe, joy, inspiration	Broaden cognitive scope; sustain engagement and future-oriented motivation	Art can inspire hope and wonder, enhance connection to nature, and generate reflection through beauty and awe	Ojala (2012); Keltner & Haidt (2003); Shiota et al. (2007); Klöckner et al. (2021); Kaufmann et al. (2023)
Negative affect	Fear, anger, sadness, discomfort	Heighten urgency and moral engagement; may backfire if not balanced with efficacy	Art can evoke discomfort or moral tension to confront environmental problems, provoking reflection and action	Lerner et al. (2003); Markowitz & Shariff (2012); O'Neill & Day (2009); Sommer et al. (2019); Cunsolo & Ellis (2018)
Mixed affect (balanced framing)	Emotional tension, empathy, discomfort	Integrates positive and negative affect to maintain engagement while avoiding apathy	Art balancing distress with hope or empathy enables sustained reflection and moral readiness to act	Curtis (2014); Sommer et al. (2019); Kaufmann et al. (2023)

CHAPTER 3

RESEARCH METHODOLOGY

This chapter presents the methodology chosen to achieve the study's objective of influencing building users' sustainable behavior. The framework is grounded in the Design Science Research (DSR) methodology. The chapter begins with an overview of DSR, followed by sections that correspond to the stages of the DSR process: identifying the research problem, outlining the data-to-art framework as part of the design cycle, and concluding with the evaluation of the artifact to assess how effectively it addresses the project's hypothesis.

3.1 Design Science Research (DSR) methodology

The DSR technique has its roots in the science of the artificial, according to the philosophy of science. In fact, it is an approach that is based on creating an artifact to address a real problem in industry or research (Hevner et al., 2004). Although there are other DSR methodology process schemes, Peffers et al. (2007)'s is the most widely used. Peffers and his colleagues' text served as the foundation for all the most recent DSR methodology applications. Therefore, we organized the material of this chapter using the six DSR stages that Peffers et al. (2007) established: Motivation and problem identification; The definition of the objectives for a solution; Design and development of the artifact; Demonstration; Evaluation; and Communication (De Sordi, 2021). Figure 3.1 shows the main steps of the DSR methodology. The process accommodates different entry points as well, such as problem-centred, objective-centred, design-centred, or client-centred, depending on the research context. The overall aim is to provide a structured framework for producing artifacts that solve real problems while generating contributions for both practice and research (Peffers et al.,2007).

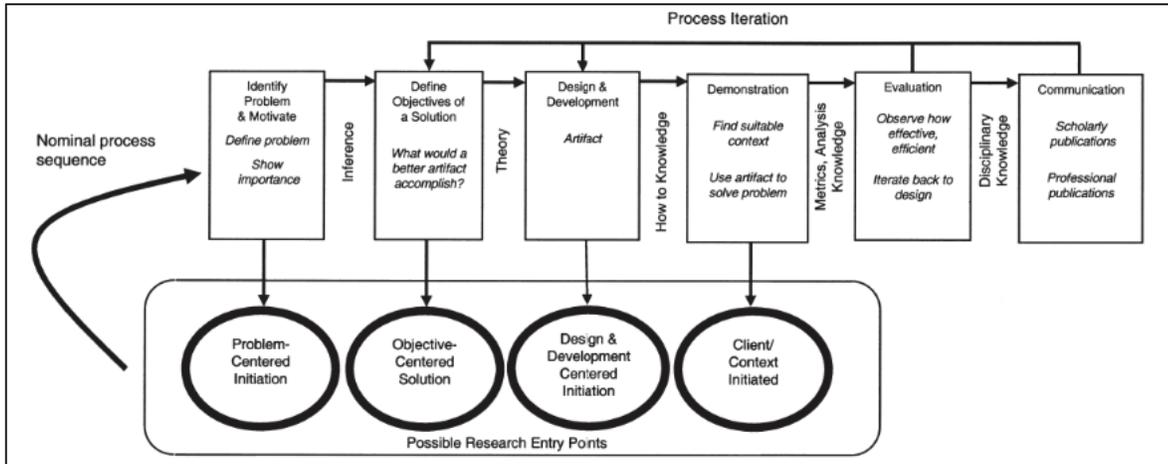


Figure 3.1 Design Science Research (DSR) methodology process
Taken from Peffers et al. (2007, p.11)

DSR is motivated by the desire to improve the environment by the introduction of new and innovative artifacts and the processes for building these artifacts (Simon, 1996). An application domain consists of the people, organizational systems, and technical systems that interact to work toward a goal. In this chapter, the different steps of the methodology are explained in the context of this research. The methodology results in an artifact designed as a framework for transforming smart building data into a tangible experience for occupants through an art installation.

3.2 Research Motivation

As noted in the introduction, the overall motivation for this research has already been established. In this section, these motivations are revisited and specified in two complementary dimensions:

- People's behavior in practice

The first motivation arises from concerns about sustainable behavior among building occupants and the curiosity of how to engage them effectively.

- Literature gap and problem in practice

The second motivation stems from the literature gap, highlighting the need for a new solution beyond energy dashboards, technical user interfaces, or awareness campaigns.

3.3 Problem statement, research questions

Building on the gaps identified in the research motivation, the first issue we address is the limited effectiveness of existing methods to represent building data and encourage sustainable occupant behaviour. While generative art has been studied in some contexts, its potential within smart buildings as an engaging medium that stimulates both affective and cognitive engagement remains underexplored. In addition, the integration of environmental psychology and empirical studies, specifically the role of emotions in supporting pro-environmental behaviour and in evaluating such interventions, has not been sufficiently implemented.

The motivation and identified gaps shaped the following research questions:

1. How does an emotionally engaging installation influence pro-environmental behaviour in smart buildings?
2. In what ways can environmental art, and specifically generative data art, enhance data representation and foster empathy among occupants?

3.4 Research Objectives

The literature review revealed the inefficiency of existing methods for representing smart building data, which often fail to engage users meaningfully. The first objective of this research was therefore to identify an approach that could present building data in a more sensible and impactful way, to foster pro-environmental behaviour among occupants. Building on this, a second objective emerged: to investigate how environmental art could be implemented as a medium to communicate building data through emotional engagement and empathy. This direction led to the integration of generative art methods, resulting in the development of a data-to-art framework capable of translating building performance data into meaningful artistic representations.

3.5 Artifact design and development

The artifact development consists of two main parts, presented here in sequence. The first part, Data Processing and Sustainability Assessment, involves reading the data and preparing it for analysis and sustainability evaluation. The second part, Data Representation, covers the technical process of transforming numerical data into visuals. The main challenge was to develop a framework that could analyze building data in terms of sustainability and then use that framework to display the quality and fluctuations of the data in a way that provokes emotions in the user.

3.5.1 Data Processing and Sustainability Assessment

The framework was developed and applied using data from a university campus as a case study. For the art installation, the dataset was further narrowed to the university library, which served as the designated site for implementation. The data for this project was collected from both equipment and sensors through the Building Automation System (BAS) platform of a university building, named Metasys. To streamline the data flow into the art framework, we used an SQL-based system to extract information and export it as CSV files, a simple and widely accessible format. This choice made the data easy to integrate into the visual tools used for the installation and ensured that it could be accessed by people from diverse fields, including artists, designers, and sustainability experts, without requiring technical expertise in building systems. The process was designed to remain flexible, allowing the dataset to be updated, modified, or expanded with additional environmental information when needed. While this approach was not based on a formal data standard, it followed the principles of open data by ensuring that the information was easy to share, interpret, and reuse.

The database was organized into sets of relational tables (Figure 3.2), each representing a factor such as time, location, indicator type, units, and measured values. Using SQL Server Management software, we identified the sensors and equipment associated with the library zone and linked the relevant tables to isolate their data. By synchronizing these tables, we were

able to extract trends and patterns in environmental conditions, such as temperature and airflow, which were later used in the data-to-art framework. As a first step, we embedded a sustainability assessment to normalize the various indicators and map them on a scale between 0 and 1. This allowed us to link each data point from the sensors and equipment in the library to its corresponding location on the building map and visualize it as part of the generative system.

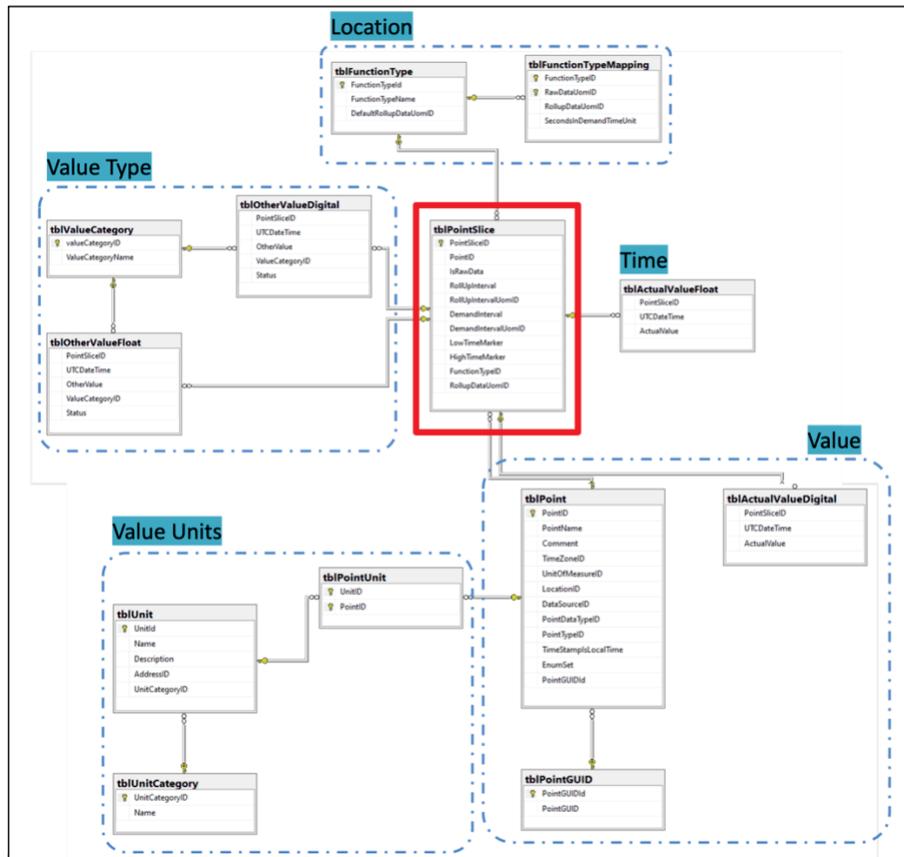


Figure 3.2 Relational database schema linking time, location, units, and measured values to extract sensor data for the data-to-art framework

Table 3.1 summarizes the main components of the Building Automation System (BAS) used in this project, including their functions, how they connect within the system, and the communication protocols they rely on. These components, ranging from the central management software (BMS) and network engine (NAE) to field controllers, sensors, and actuators, form the backbone of the data infrastructure. Together, they enable the monitoring

and control of environmental conditions, while also generating the building performance data later processed in the sustainability assessment and visualization framework.

Table 3.1 Components of the Building Automation System (BAS), their functions, connections, and communication protocols

Component	Function	Connected To	Communicates
BMS (Building Management System – Metasys)	Main software that monitors & controls the building.	Communicates with NAE/NEE over Ethernet/Wi-Fi.	Ethernet, Wi-Fi
NAE (Network Automation Engine)	The brain of the system; centralizes data from VAVs, sensors, and HVAC units.	BMS, Field Controllers (FC), UTA	BACnet/IP (Ethernet), MS/TP (RS-485)
FC (Field Controller)	Manages multiple VAVs and HVAC components in a zone.	VAV controllers, temperature sensors, air dampers	RS-485 (wired), BACnet MS/TP
VMA (VAV Modular Assembly)	Controls airflow for individual rooms/zones; adjusts dampers.	Air ducts, temperature sensors, occupancy sensors	Wired to FC via RS-485 or BACnet MS/TP
UTA / AHU (Air Handling Unit)	Supplies fresh air; heats/cools air before sending it to VAVs.	Fans, filters, heating/cooling coils	BACnet/IP (Ethernet) or BACnet MS/TP
Sensors & Actuators	Measure temperature, humidity, CO ₂ , airflow.	Connected to VAVs, FCs, and UTA	Wired (RS-485) or wireless (Zigbee, Wi-Fi)

In the data framework, temperature and airflow data were imported from the building automation system (BAS). Rather than treating these values as direct measures of sustainability, they were interpreted as indicators of the effort required by the building systems to maintain indoor comfort under varying external conditions. Temperature thresholds were derived from BAS-defined operational setpoints, which vary by season, time of day, and occupancy status. As shown in Table 3.2, these ranges correspond to comfort-oriented indoor conditions rather than optimal sustainability targets. For this study, data from February during daytime occupied hours were analyzed, a period characterized by low outdoor temperatures and increased heating demand.

Table 3.2 Optimal temperature thresholds by season and occupancy condition, as defined in the BAS

Season	Condition	Temperature Range (°C)
Summer	Daytime (Occupied Hours)	22 – 24
	Nighttime (Unoccupied Hours)	24 – 27
Winter	Daytime (Occupied Hours)	20 – 22
	Nighttime (Unoccupied Hours)	16 – 18

Airflow was regulated by the VMA (VAV modular assembly) on a zone-by-zone basis and measured in litres per second. These airflow values were not interpreted as direct energy measurements but were used as a relative proxy for energy-related system activity, particularly during winter operation. Higher airflow volumes generally correspond to increased fan power and heating demand required to maintain comfort conditions in occupied spaces. The airflow thresholds shown in Table 3.3 represent ventilation requirements designed to ensure acceptable indoor air quality based on occupancy or area.

Table 3.3 Airflow requirements by library zone, expressed in litres per second (L/s) according to occupant load or area-based thresholds

Zone / Space	Occupants	Outdoor Airflow Requirement (L/s)
Study Rooms (11–13 m ³ each)	4–6 places	~20–25
Staff Offices (11–12 m ³ each)	1–2 places	~6–10
Activity Classrooms (60 m ³)	20–30 places	~100–150
Open Study Area 1 (314 m ³)	50–80 places	~150–250
Open Study Area 2 (158 m ³)	30–50 places	~100–150
Open Study Area 3 (141 m ³)	20–40 places	~80–120
Open Study Area 4 (140 m ³)	20–40 places	~80–120
Stacks (541 m ³)	—	~32 (area-based only)

Within the data-to-art framework, temperature and airflow were therefore treated as complementary indicators: temperature reflected the experienced level of thermal comfort, while airflow reflected the system’s effort and associated energy demand required to achieve that comfort. Each data stream was compared against its corresponding operational range to identify relative increases or decreases in system’s intensity. These indicators were then

visualized through color-coded displays, enabling intuitive interpretation of building performance.

3.5.2 Data Representation

There are many platforms available for interpreting data, but for this project, we needed a medium capable of handling numerical values, shapes, and images in a practical and flexible way. To achieve this, we used a visual programming software widely applied in multimedia generation. This platform gave us the flexibility to continuously import streams of data, normalize them, and transform them into different visual forms (Figure 3.3). It is with the help of TouchDesigner engine that we can transform numerical data to graphical and map the shapes to eventually an image-to-image stable diffusion output.



Figure 3.3 TouchDesigner Generative Design Examples
Taken from [www.simonaa.media/tutorials/daily-practice]

To refine the generative visuals, the project used an embedded version of the *Stable Diffusion* model integrated with a computer render server inside the visual programming environment. This setup made it possible to control the model parameters interactively, using both text-based prompts and numerical settings, while still allowing access to the underlying code for further customization.

The model was guided by textual prompts to ensure that the output aligned with the ecological metaphor of the wood lily. Several parameters were tuned during the process (Figure 3.4):

- Iterations (Steps): Each iteration refines the image progressively from random noise toward the target prompt. More iterations increase visual detail and coherence but also require more computational time. In this project, iteration counts were adjusted to balance fidelity with real-time responsiveness.

- **Guidance Scale:** This determines how closely the image follows the text prompt versus the underlying generative variation. Higher guidance values produce images more faithful to the prompt (e.g., recognizable floral structures), while lower values allow more creative, abstract forms. By experimenting with this scale, the visuals could range from abstract organic textures to recognizable lily-like flowers.
- **Strength:** This controls how much of the initial generative input (from the TouchDesigner shapes) is preserved when Stable Diffusion modifies it. Lower strength keeps the geometry closer to the input generative form, while higher strength allows greater transformation into fully naturalistic floral imagery.
- **Seed:** Each rendering starts from a random seed value, which influences variation in the output. Fixing the seed ensures reproducibility of a particular flower form, while varying the seed produces diversity in the generative garden.

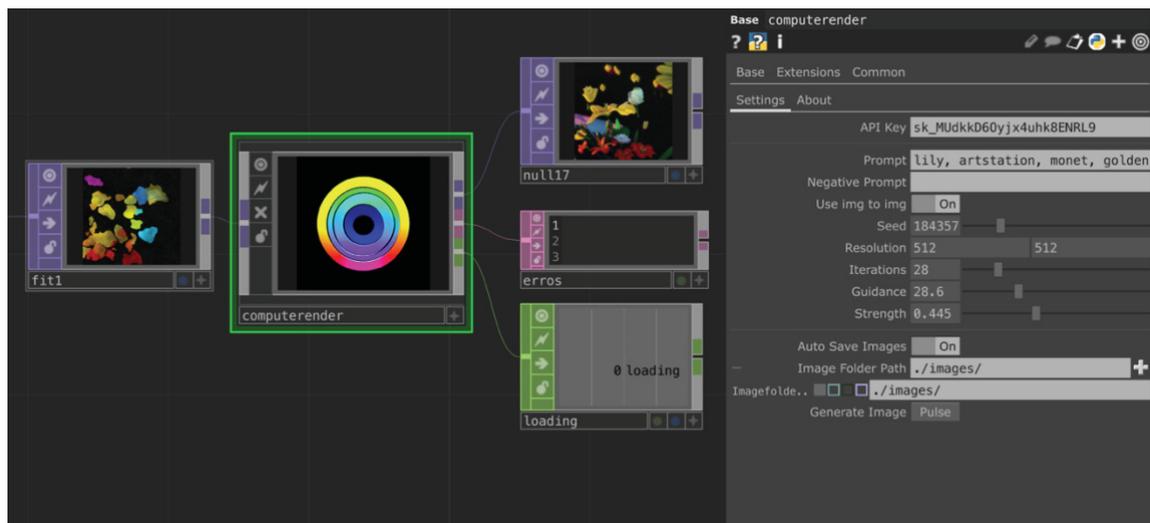


Figure 3.4 Embedded Stable Diffusion in TouchDesigner

By combining these controls, the system transformed abstract generative shapes into floral motifs that symbolically represented building performance. The process allowed a balance between algorithmic variation (ensuring the garden evolved dynamically) and prompt-driven coherence (ensuring the flowers retained their ecological symbolism).

3.6 Evaluation

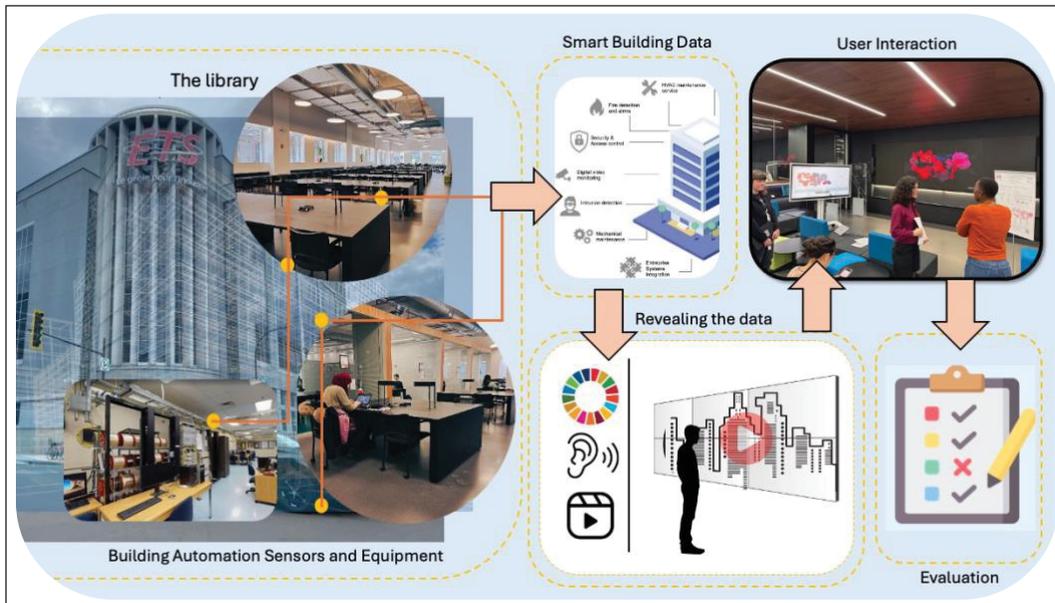


Figure 3.5 Overview of the research process: from building sensor data collection to generative art representation, user interaction, and evaluation

As a result of the artifact development, the Garden of Sensors installation was created, transforming building sustainability data into an interactive, meaning-making interface for building users. The installation was experienced in a public setting, allowing participants to engage with the visual representations and reflect on their relationship with the building and its environmental performance (Figure 3.5).

Given the interdisciplinary nature of the project, an evaluation approach was required that could capture experiential, emotional, and interpretive dimensions rather than solely technical performance. Based on prior work on pro-environmental behavior and behavior change discussed in Chapter 2, a qualitative survey-based method was selected to assess participants' responses to the installation.

Within the Design Science Research cycle, evaluation serves to determine whether the artifact fulfils its intended purpose. In this study, evaluation was guided by an integrated conceptual framework (Figure 3.6) drawing on empirical aesthetics and environmental psychology. Rather

than testing usability or performance metrics, the evaluation focused on how the installation elicited emotional engagement, cognitive reflection, and articulated intentions related to sustainability. This framework enabled the assessment of how participants interpreted the data representation, how emotions shaped reflection, and how these experiences related to perceived pro-environmental intention. In this way, the evaluation phase extends beyond functional validation to assess the artifact's ability to support reflection and meaning-making, which constitutes the core objective of this research.

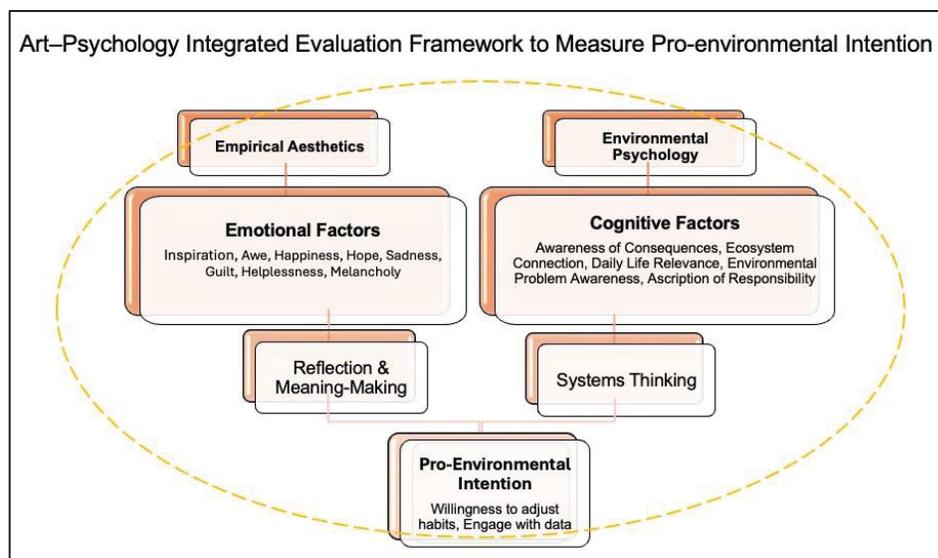


Figure 3.6 Evaluation framework

Measuring the effect of emotions through art is challenging, but combining empirical aesthetics (Leder et al., 2004; Pelowski & Akiba, 2011; Silvia & Nusbaum, 2011; Vessel et al., 2012) and environmental psychology (Schwartz 1977; Ajzen & Fishbein, 1980; Allen & Ferrand, 1999; Arbuthnot, 1977; Stern, 2000; Cialdini, 2003), we created a list of positive and negative emotions that trigger meaning-making and reflection through art, showing how art can affect people. Using environmental psychology, we included cognitions and measured them with theories like Value-Belief-Norm, which leads to systems thinking. We also assessed intentions to act pro-environmentally, and considered covariates such as age, education, and art experience that could influence these factors. Both emotional and cognitive measures are extensively examined in the literature review of this thesis.

Based on the literature reviewed in Chapter 2, pro-environmental theories were incorporated into the questionnaire. Table 3.4 shows how a mix of “Awareness of consequences,” “Ascription of responsibility,” “Relevance for daily life,” “General reflections,” and “Systems thinking” was applied.

Table 3.4 Mapping of cognitive reflection questions to underlying psychological constructs

Cognitive Statement	Represents	Theoretical Basis
1. This data representation made me reflect on resource consumption in this building.	Awareness of environmental impact of personal/local resource use	Stern (2000): Awareness of consequences (VBN)
2. This data representation made me reflect on local ecosystems and biodiversity.	Systems thinking; awareness of ecological interdependencies	Molderez & Ceulemans (2018): Systems thinking, Environmental cognition
3. This data representation helped me better understand how daily activities affect sustainability in this building.	Relevance to daily life; linking personal actions to broader environmental outcomes	Stern (2000): Relevance for daily life (VBN)
4. This data representation made me think about environmental problems.	General environmental awareness; stimulus for reflection on abstract/systemic issues	Gifford (2014) Cognitive reflection, Awareness of consequences
5. This data representation made me more aware of my behaviour’s impact on the environment.	Ascription of responsibility; realization of personal role in environmental outcomes	Stern (2000): Responsibility (VBN), Pro-environmental norms

This framework positions emotional factors (e.g., awe, inspiration, guilt) and cognitive factors (e.g., awareness of consequences, daily life relevance, ascription of responsibility) as mediators that link the installation experience to pro-environmental intention. Reflection, meaning-making, and systems thinking are understood as processes through which emotions and cognition translate into behavioural motivation. The evaluation hypothesis was “Higher emotional (both negative and positive) and cognitive responses are positively associated with higher pro-environmental behavioral influence.”

3.7 Research communication

The last phase in the DSR process is research communication. De Sordi (2021) states that this stage needs to consider two reader groups: researchers and professionals. As a result, the publication of this thesis is presented in the following chapter. The article has been submitted to the Journal of Energy Research and Social Science. It is in the phase of Revisions now.

This article introduces a data-to-art framework that transforms building performance data into generative representation inspired by vulnerable native species. It presents the development and evaluation of the digital art installation ‘Garden of Sensors’ as a possible implementation of this theoretical framework. By combining principles from environmental psychology, behavioral science, and generative design, the study examines how emotionally engaging representations of environmental data can influence users’ reflection, emotions, and intentions toward sustainability. The article reports both the conceptual foundation and empirical results of this installation, demonstrating how art can serve as an affective interface between people and the invisible dynamics of building performance.

CHAPTER 4

DATA ART TO ENHANCE USERS' PRO-ENVIRONMENTAL BEHAVIOR

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4.1 Abstract

Promoting sustainable behavior among building users remains a challenge, particularly in smart buildings where environmental data is often delivered through dashboards that lack emotional resonance. This study explores the potential of data-driven art to deepen pro-environmental awareness and intention by transforming building sustainability data into an affective, reflective experience. A flexible data-to-art framework was developed that can integrate diverse building data streams (e.g., temperature, airflow, waste, water, or energy use) and adapt them into multisensory formats such as sound, haptics, or interactive visualizations.

The *Garden of Sensors* installation, created and exhibited at the École de technologie supérieure (ÉTS) university library, was designed not to instruct users but to evoke emotional and cognitive engagement with building data. In this implementation, ventilation airflow was used as an energy-related operational indicator, while room temperature was treated as a proxy for thermal comfort, and both were translated into generative visual forms, illustrating only one possible configuration of the framework. A qualitative questionnaire with 43 participants examined how users described their emotional responses, cognitive reflections, and intentions toward future environmental behavior.

The findings suggest that uplifting emotions, particularly inspiration and hope, were most often associated with reflective thought and expressed willingness to adopt sustainable habits. In contrast, heavier reflective emotions such as guilt or melancholy tended to prompt introspection without leading to stated intention. Overall, the results indicate that data-driven art can function as a perceptual and emotional interface, making invisible environmental processes perceptible and personally meaningful. This approach holds promise for integration into libraries, campuses, corporate lobbies, or public spaces, offering a novel pathway to foster environmental awareness and support pro-environmental engagement in everyday settings.

Keywords: Smart Buildings, Building Performance Data, Pro-environmental Behavior, Environmental Psychology, Emotions, Environmental Art.

4.2 Introduction

Buildings account for 23% of Canada's primary energy consumption, primarily driven by the need to ensure comfortable indoor environments (Enerdata, 2024). The adoption of smart building technologies, including sensors and automated systems, has greatly improved operational efficiency and energy use (Ceccarini et al., 2021). These systems enable real-time monitoring and adaptive control of building conditions. However, despite these advances, occupant behavior remains a major variable influencing energy outcomes, one that is often underestimated in building performance simulations (Deng & Chen, 2019). Actions such as thermostat adjustments or window use can introduce deviations of up to 150% from predicted energy use. As buildings become more automated, human engagement diminishes, yet sustainability outcomes still rely on user cooperation and behavior.

Most strategies for influencing occupant behavior involve providing feedback through dashboards, mobile apps, or interfaces that display energy or comfort data (Timm & Deal, 2016; Mohammadi et al., 2025). These tools make environmental data more accessible, but they often fall short of changing beliefs or behaviors (Sommer et al., 2019). While they may increase awareness, they tend to lack emotional impact and personal relevance. According to environmental psychology, how people feel about their environment has a stronger influence on behavior than knowledge alone (Gifford, 2014). Presenting building data in detached, technical formats risks disengaging users rather than empowering them.

Achieving sustainability requires not only rational understanding but emotional commitment. The arts have long served as a medium for emotional communication and value formation (Shrivastava et al., 2012). In environmental communication, environmental art provides compelling examples of how artworks can engage values and emotions. Curtis, et al. (2014, as cited in Sommer et al., 2019) examined how artworks portray environmental issues and shape public perception, concluding that environmental art can encourage pro-environmental behavior by (1) communicating information in engaging ways, (2) fostering empathy for natural spaces, and (3) enhancing sustainability projects by making them more appealing to the public (Curtis et al., 2014, cited in Sommer et al., 2019). According to Marks (2015), environmental art emphasizes the artist's aim more than the medium or format, and it can range from multi-media performances to a sculpture made of natural and repurposed materials (Weintraub 2012).

Emotionally charged artworks can spark reflection, empathy, and a sense of urgency, qualities essential to motivating sustainable behavior (Chevalier & Diamond, 2010). Emotional resonance, rather than cognitive awareness alone, is often what drives people to act (Smollan, 2006). As such, embedding environmental data in artistic forms offers a promising strategy to connect people more deeply to sustainability.

This project applies data-driven approaches, using generative methods to translate building performance data, ranging from sensor readings (e.g., temperature, airflow) to equipment

metrics (e.g., heating regimes, hourly energy consumption), into evolving visual forms. Powered by algorithms and AI, generative data art creates dynamic visual systems that respond to data inputs (Dulic & Thorogood, 2019; Galanter, 2003). This makes it well-suited for visualizing building performance conditions in ways that are both informative and emotionally engaging. Unlike static dashboards, such installations transform abstract performance information into living aesthetic experiences that reveal environmental change and complexity. Prior work has explored generative design in buildings and sensor interfaces (Ceccarini et al., 2022), but little is known about how these approaches affect occupant emotions, cognition, or sustainable intentions.

The Garden of Sensors was developed as an installation designed to emotionally and cognitively engage building users with building performance data. Installed in the university library, the work aims to raise awareness of environmental performance through generative data art inspired by vulnerable native species. The research investigates how such an emotionally resonant data representation influences users' emotional responses, reflections on sustainability, and intentions to act. Drawing on theories from environmental psychology and behavior change, we assess whether data art can serve as a perceptual bridge, connecting building occupants to invisible environmental feedback through beauty, symbolism, and emotion.

This paper addresses the gap between data accessibility and emotional engagement in building performance communication. We propose that data-driven generative art can bridge this gap by transforming abstract metrics into emotionally resonant experiences. After outlining the behavioral theories and environmental metrics guiding our evaluation strategy, we review examples of environmental and data-based art in building contexts. We then present the Garden of Sensors installation, its methodology and findings, and conclude with a discussion of how such artistic interventions may foster sustainable behavior.

4.3 Literature Review

4.3.1 Behavior Change and Pro-Environmental Behavior (PEB)

Promoting pro-environmental behavior (PEB) among building occupants is critical to achieving sustainability, especially in smart buildings where energy-efficient systems alone cannot ensure reduced consumption. While technological innovations improve energy performance, the human element often introduces significant variability (Deng & Chen, 2019). Studies indicate that neglecting human aspects can significantly affect building sustainability, with occupants accounting for 30% to 50% of building energy use (Sun et al., 2014). Occupant responses to environmental stimuli, such as temperature, CO₂ levels, and solar radiation, directly influence control over windows, blinds, HVAC systems, and ventilation (Haldi & Robinson, 2008; Lin et al., 2016; Dimitrova et al., 2022). These examples highlight the complex interplay between environmental conditions and building control systems.

To address these challenges, various initiatives have aimed to raise awareness and influence user behavior through real-time energy information. For example, Timm & Deal (2016) utilized real-time energy information dashboards within four community college campuses, emphasizing the dynamic role of immediate visual feedback in influencing energy conservation behaviors. Similarly, Olsen (2014) designed a mobile app inspired by eco-visualization to display real-time household energy consumption, merging data from advanced measurement tools with social media elements to encourage sustainable behavior.

Other studies, such as Čiarniene et al. (2020), emphasize how demographic and psychological factors such as generation, education, and attitudes, shape sustainable behavior, indicating that effective engagement must consider user diversity (Zebracki, 2011). A broader integration of behavioral science into building sustainability strategies is essential. By identifying which cognitive and emotional factors most influence user behavior, designers can better support energy goals through psychologically informed interventions.

4.3.2 The Role of Art in Environmental Communication

Research into sustainable behavior showcases a variety of approaches, highlighting that PEB is influenced by a blend of cognitive, moral, and emotional values (Chan & Bishop, 2013; Greaves, Zibarras, & Stride, 2013; Horlings, 2015; Jakovcevic & Steg, 2013; Poškus, 2016). These dimensions are central to driving societal transformation toward environmental responsibility (Alroe et al., 2017). In this context, PEB is defined as behavior aimed at minimizing negative impacts on the natural or built environment (Kollmuss & Agyeman, 2002).

Historically, theories assumed a direct correlation between increased environmental knowledge and sustainable actions. However, this assumption has been disproven, showing that knowledge alone does not lead to pro-environmental action (Kollmuss & Agyeman, 2002). Instead, the Theory of Planned Behavior suggests that an individual's intent, shaped by attitudes, subjective norms, and perceived control, serves as a more reliable predictor of environmental behavior. This theory, alongside the Value-Belief-Norm (VBN) theory, emphasizes the importance of integrating moral values into rational decision-making frameworks. Stern (2000) expands on this by categorizing value orientations into altruistic (social), egoistic, and biospheric. Each orientation influences environmental concern to varying degrees. The collective influence of these orientations can define motivation, highlighting how different value orientations combine to drive environmental behaviors.

This intersection of individual perception, emotion, and decision-making is a key focus of environmental psychology, which investigates how people relate to their physical surroundings and how these relationships influence environmentally responsible behaviors (Gifford, 2014). Environmental psychology emphasizes that affective and perceptual experiences, not just cognitive knowledge, play a central role in motivating sustainable actions. In this context, the arts act as a powerful mediator of environmentally relevant emotions, such as awe, guilt, empathy, or hope, which research shows are often precursors to behavioral change.

4.3.3 Art as a Bridge Between Knowledge, Emotion, and Action

The arts play a crucial yet underappreciated role in this context. They not only foster moral improvement and shape values but also serve as a medium to raise awareness and influence attitudes toward environmental sustainability (Belfiore & Bennett, 2007; D. J. Curtis, 2011; Fien, 2003). Unlike technical communication strategies, art operates on an emotional and experiential level, helping people feel what is at stake.

The persuasive power of the arts, recognized since Aristotle, can effectively align cognitive understanding with emotional engagement and practical action. This integration is essential for effecting behavioral change, as it bridges the gap between abstract knowledge and tangible actions. Marda Kirn (Figure 4.1) conceptualizes this relationship through the head–heart–hands framework, emphasizing transdisciplinary collaboration. In this model, scientists bring the “what” (facts and reasoning), artists contribute the “so what” (emotions and values), and sustainability practitioners deliver the “now what” (actions and solutions). Only when these domains interact can meaningful environmental transformation occur.

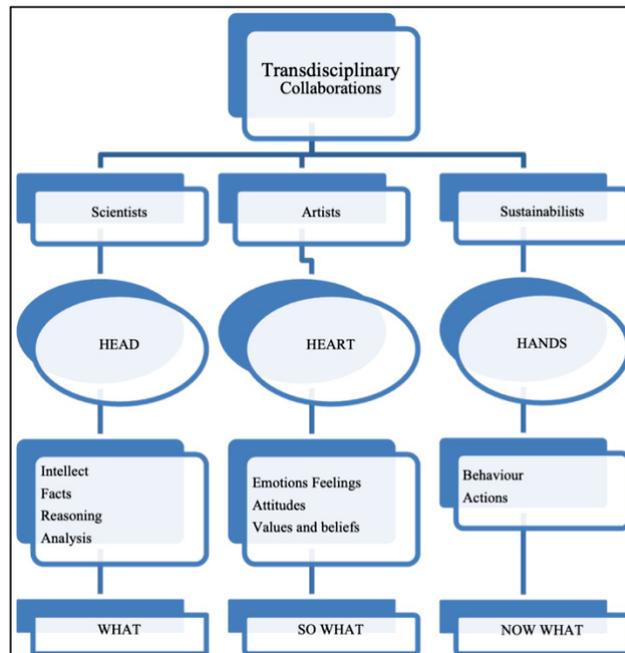


Figure 4.1 Framework illustrating interactions between the arts, science, and sustainability practitioners in collaborative

Beyond inspiring emotional response, art actively contributes to pro-environmental behavior through multiple channels. It affects belief systems, communicates complex ideas in accessible formats, and cultivates empathy for the natural world. This is illustrated in Figure 4.2, which outlines the pathways through which art contributes to environmental sustainability. It begins with influencing beliefs and values, leads to information-sharing and empathy, and ultimately supports behavioral change that contributes to sustainability goals.

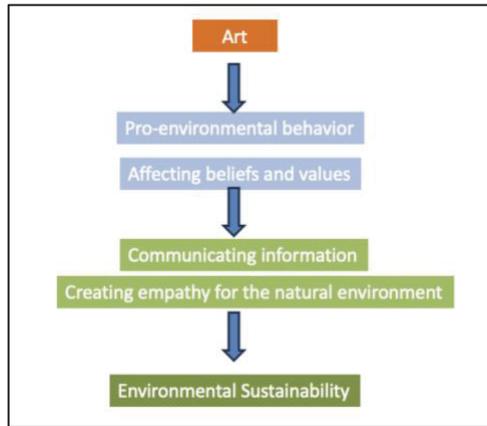


Figure 4.2 Pathways through which the arts can be used to help achieve environmental sustainability
Adapted from Curtis (2014)

These figures suggest that the arts are not peripheral to environmental discourse but integral. They provide cultural depth, narrative power, and emotional entry points that allow data and policy to connect with the public in meaningful ways. Several examples illustrate this potential.

A powerful example of art influencing environmental behavior is *Pollution Pods* by Michael Pinsky. This immersive installation recreated the air quality of five global cities, allowing visitors to physically experience pollution levels. Research showed that the emotional and sensory impact increased awareness and strengthened intentions to act more sustainably (Sommer et al., 2019). The work demonstrates how art can transform abstract environmental data into felt, personal experience that prompts reflection and behavior change.

Welsby's (2011) installation, *Tree Studies*, implemented weather data that dynamically responded to environmental changes. These installations are not just passive displays but active participants in a larger ecological dialogue. They highlight the intimate and complex relationship between technology, nature, and art. These artworks reflect the dynamic equilibrium necessary for survival, where technology collaborates with natural forces, creating a visual narrative where art and nature coalesce, urging a deeper reflection on our place within the natural world and our responsibilities towards sustaining it.

Adding a sensory dimension to this narrative is proposed by Bonet (2019), whose research into the sonification of data enriches the tapestry of data-based art with an auditory layer, suggesting that hearing data can impact our understanding and response to sustainability in profound ways. The dynamic settings of intercollegiate competitions, as observed by Garud et al. (2022), demonstrate how art installations utilizing real-time data can captivate and educate, underscoring the urgency of environmental stewardship and propelling the message.

These examples show how data-based art transforms abstract environmental metrics into felt, embodied experiences. Yet, a key gap remains: few studies have examined whether such emotional experiences lead to actual behavioral influence, particularly in the context of smart buildings. This gap motivates the current study.

4.3.4 Generative Design and Data-Based Art in Building Context

Generative art, as defined by Philip Galanter, is an art practice where the artist employs autonomous systems, such as algorithms or physical processes, to produce evolving works (Galanter, 2003, 2008). In the context of sustainability, this approach is particularly relevant: it mirrors the adaptive, nonlinear dynamics of ecological systems, and fosters interdisciplinary engagement necessary for tackling complex environmental issues (Soddu, 1998; Kagan, 2010). In the context of smart buildings, vast amounts of data are generated by sensors and equipment and collected within building management systems (BMS). Thus, this data becomes the primary material for representation. Different approaches are trying to use this data to present the information to non-expert users. Ceccarini et al. (2022) explored how user-centred interfaces that visualize building sensor data can increase occupant awareness of indoor environmental conditions in the university setting. Their study involved designing an interactive touchscreen interface for a smart campus that displayed real-time environmental data (e.g., temperature, brightness, humidity) overlaid on a map-based floor plan. Through structured interviews with students, they found that the ability to visualize data contextually, especially through intuitive color schemes and icons, significantly improved users' interest and

comprehension. Importantly, their findings suggest that non-expert occupants are not only interested in this data but also influenced by it in how they select and engage with spaces.

Beyond technical interfaces, artistic practices have begun engaging with building data in more affective and experiential ways. A compelling example of art integrated into a smart building context is Stephen Kelly's long-term media installation at Dalhousie University's Mona Campbell Building. Developed in collaboration with architects, engineers, and computer scientists, the piece responds in real time to data from the building's environmental control systems. Installed in a LEED-certified facility, it uses light and subtle motion to visualize the building's internal conditions, continuously reflecting its energy flows and ecological "mood." As an ambient media artwork, it exemplifies how art can operate as a non-intrusive, embodied interface, engaging users with sustainability through presence rather than instruction (Kelly, 2013).

In summary, the reviewed literature highlights that while smart building technologies generate extensive environmental data, occupant behavior remains a decisive factor in building performance. Traditional data communication strategies often fail to emotionally engage users, whereas art has been shown to evoke meaningful emotional responses and reflections that can support pro-environmental behavior. The intersection of environmental psychology, behavioral theories, and artistic practice reveals that emotional resonance, cognitive reflection and personal relevance are key mediators between awareness and behavioral intention.

Expanding further, traditional artistic practices are increasingly being transformed through data science and generative systems. While generative art offers a compelling medium, its wider application, impact, and assessment on the sustainable behavior of building users and occupants have not yet been investigated. Hence, another way to render data more comprehensible is through generative art powered by AI, providing a more flexible and interactive platform to interpret data in various contexts. Generative AI acts as an expansion of the artist's palette, enabling the exploration of new creative territories (Epstein et al., 2023). Even though the Generative AI is based on system computation, it is trained by a human.

Cetinic & She (2021), have done a full review on AI's role in creating new artworks and claim Generative AI has distinct cultural context and material affordances that make it a unique new artform. This study aims to explore the uses of data-driven generative art and evaluate the influence on the user pro-environmental behavior.

The methodology of the current research employs a generative art installation to translate sensor data into emotionally engaging visuals. By integrating building performance data with emotionally symbolic imagery, specifically the wood lily, the study operationalizes theoretical insights on emotion, cognition, and behavior into a tangible intervention. Thus, the literature not only justifies the choice of a generative data art methodology but also helps shape the evaluation framework, which includes emotional, cognitive, and intentional metrics aligned to enhance pro-environmental engagement through emotionally resonant design.

4.4 Research Methodology

4.4.1 Design Science Research

Following the identification of gaps in the literature, this study aims to develop a methodological framework to effectively promote sustainable behavior in buildings through design. This study is situated at the intersection of environmental psychology, human-computer interaction, and generative art, and employs the Design Science Research (DSR) framework. DSR, described in six phases by De Sordi (2021), motivation and problem identification, definition of objectives for solutions, design and development of an artifact, demonstration, evaluation, and communication, provides the structure for the research process. The approach integrates an art-based intervention with both qualitative and quantitative evaluation, combining experiential insights and survey data to investigate the impact of emotionally resonant, data-driven art on occupants' environmental awareness, cognitive reflection, and behavioral intentions in a smart building context.

The research design is informed by several key motivations:

- First, promoting pro-environmental behavior among building users is crucial, as human actions strongly impact sustainability.
- Second, prior literature emphasizes that technical feedback mechanisms (e.g., dashboards and apps) often fail to evoke meaningful emotional responses, which are known to influence sustainable behavior more strongly than awareness alone (Gifford, 2014).
- Third, while generative art has been explored as a medium for environmental data representation, its role in stimulating affective and cognitive engagement, especially within the spatial and social context of smart buildings, remains underexplored.

In this research, our goal is to develop an artifact that responds to the main objective of implementing a data representation capable of influencing the pro-environmental behavior of building users. The elaboration of the framework began with the design and development of a site-specific generative art installation, *Garden of Sensors*. This installation was designed to translate environmental sensor data into symbolic visualizations using a digital floral motif. The demonstration phase consisted of exhibiting the installation in a real-world context, specifically a university library, where users could directly experience it. Lastly, post-experience surveys assessing behavioral intention, emotional engagement, and cognitive reflection were used in the evaluation phase to gauge its efficacy. By connecting problem identification, artifact creation, practical application, and empirical validation, these steps collectively encapsulate the iterative DSR process.

This methodological framework allows for both creative exploration and qualitative empirical assessment, offering insights into how affective data representation can trigger the psychological mechanisms underlying environmental behavior change. It supports interpretation of data by connecting subjective emotional experiences to qualitative assessment of intention. By bridging artistic practice with behavioral science, this methodological framework seeks not only to evaluate the effectiveness of generative art as a communication tool but also to contribute to broader interdisciplinary discourse on the role of aesthetics,

emotion, and interaction in sustainability transitions. As shown in Figure 4.3, the six phases of DSR structure the research process, from problem identification to communication.

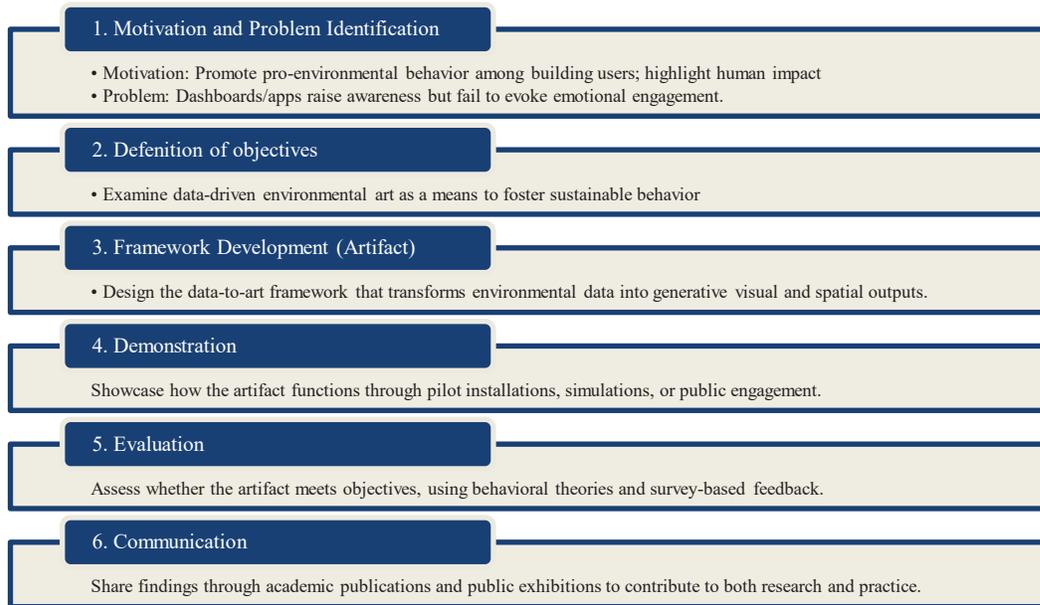


Figure 4.3 Steps of the Design Science Research (DSR) methodology used in this research

4.4.2 Development of the Installation: Garden of Sensors

Guided by our research objectives and the literature, we developed the Garden of Sensors. This data-driven art installation transforms building performance data, in this case temperature and airflow, into dynamic digital floral visuals. The visuals metaphorically represent environmental sustainability through the image of the wood lily, a vulnerable native species (NatureServe, 2025). The installation consists of two outputs: 1) A generative animation of abstract floral visuals that change based on environmental performance, and 2) A numerical dashboard displaying raw sensor values for contextual clarity.

The idea was that users interacting with this installation would begin to associate their daily activities in the building with the flowers' constantly changing states, from fresh and vibrant to withering. This visual transformation encourages reflection on their own impact, helping them connect the indoor environment with the larger natural world. In doing so, it is expected

that the installation bridges the psychological distance between human actions and their real-world environmental consequences. The behavioral theories are applied by using a vulnerable local plant to emphasize emotional influence and the inherent human connection to nature.

4.4.3 Data Collection and Processing

As shown in Figure 4.4, the installation follows a generalizable data-to-art framework that begins with the extraction of raw building sustainability data from the building management system, such as temperature, airflow, humidity, or other performance indicators. This data is then processed through an intermediate decision and interpretation layer, where trends, thresholds, and deviations relevant to sustainability and comfort are identified.

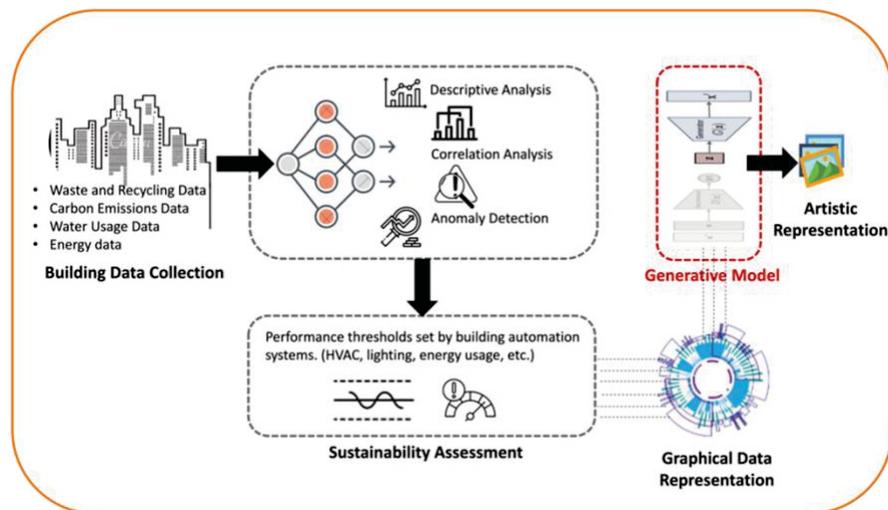


Figure 4.4 Data-to-art framework for the “Garden of Sensors” installation

The resulting structured dataset is subsequently mapped onto graphical representations, forming the final stage of the framework. While the Garden of Sensors installation implements this process through a responsive visual system, the framework itself is designed to remain adaptable to other forms of data, representational modalities, and interaction mechanisms. This

transformation of environmental data into perceptible, responsive outputs lies at the core of the generative approach explored in the following section.

To assess sustainability-related dynamics and meaningfully translate them into an expressive representation, we relied on data available from the Building Management System, specifically indoor temperature and ventilation airflow. Direct measurements of energy consumption were not accessible in this context. Instead, ventilation airflow, representing the volume of pressurized air supplied by the HVAC system to individual rooms, was used as a proxy for energy-related building operation. Ventilation airflow is closely linked to HVAC energy demand, particularly during winter conditions, when increased airflow generally corresponds to higher fan power and heating loads. In this study, airflow data were temporally synchronized with HVAC pressure trends observed during the month of February, supporting their interpretation as a relative indicator of system activity rather than an exact measure of energy use.

The dataset was collected from the Building Management System (BMS) of Pavilion A, powered by Johnson Controls' Metasys platform. These metrics were sampled over the month of February 2025, within the time frame of 7:00 AM to 5:00 PM each day. The average values for each time point across all days were calculated, producing a simulated one-day dataset compressed into a 10-minute cycle for the installation.

Existing BMS thresholds for acceptable temperature and airflow ranges were used as reference points for sustainability-oriented interpretation. Deviations from these ranges were treated as indicators of increased system effort or reduced sustainability performance and directly influenced the state of the digital garden, resulting in blooming, wilting, or decay patterns. While these values do not represent precise energy consumption, they provide an interpretable and meaningful approximation of energy-related dynamics, linked to user's comfort and suitable for data-driven representation and user engagement.

4.4.4 Generative Art

In generative artworks, structure is not fixed; it adapts continuously. This property makes generative art particularly suited to respond to fluctuating inputs and different viewing contexts. As Maturana and Varela (1980) describe through the concept of autopoiesis, generative systems are in constant self-reinvention, capable of reflecting complex ecosystems through algorithmic processes. This responsiveness is key when translating building data into visual narratives meant to provoke awareness and emotional engagement.

To execute this transformation, we used the node-based generative design platform TouchDesigner. Sensor data were streamed into TouchDesigner via Python scripts that sequentially transmitted values from the building management system database. Environmental indicators, temperature and airflow were mapped onto geometric primitives, which then evolved into organic forms. The resulting visuals formed a digital garden, capable of wilting or flourishing based on sustainability thresholds, visually encoding building performance into a poetic, reactive system (Figure 4.5).

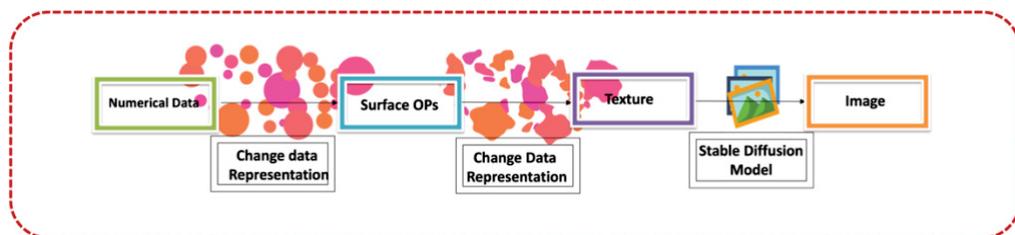


Figure 4.5 Generative art framework using TouchDesigner: transforming building performance data into geometric forms, which evolve into organic visual elements to create a dynamic digital garden

While generative shapes help to show data trends, they do not clearly express meaning. As a final step, we employed a generative AI model, Stable Diffusion. Its image-to-image feature lets us turn the organic shapes into a digital garden (Figure 4.6).

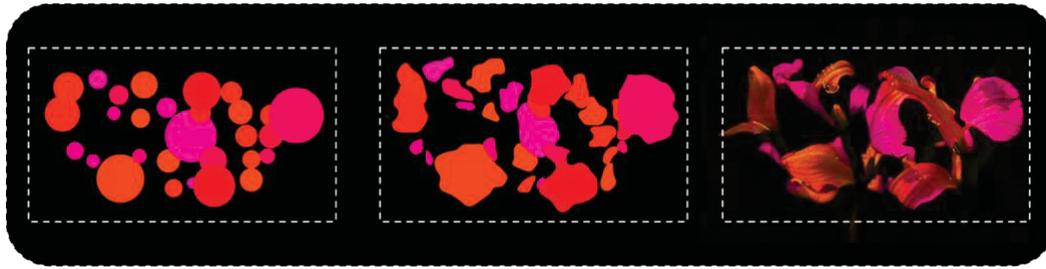


Figure 4.6 Progressive transformation of data into digital flowers using Stable Diffusion: from abstract generative shapes (left) to organic forms (center), to

The embedded Stable Diffusion model was guided by textual prompts. The prompt referenced *wood lilies* and a *Monet-inspired aesthetic*, directing the visual language in natural and impressionistic forms.

As Louv (2012), writes in *The Nature Principle*, “The more high-tech we become, the more nature we need.” We use digital tools not to distance us from nature, but to help us reconnect with it (Coles & Pasquier, 2015). To deepen the emotional connection and ecological message of the work, we introduced wood lilies as the central visual metaphor. These flowers, classified as vulnerable species in Quebec, serve as symbolic agents linking the fragile state of nature to human behavior inside the building. The lilies connect viewers to the emotional quality of encountering natural beauty, particularly poignant in urban settings such as a redeveloped industrial district of Montreal, where access to green spaces is limited.

Temperature and airflow data influence the visual representation through both color and size. Color reflects deviations from a sustainability-oriented thermal operating range rather than comfort itself. As indoor temperature shifts toward comfort-driven setpoints that require increased HVAC effort, the flowers’ colors transition from warm, natural lily tones toward cooler, desaturated shades, visually signaling increased system strain.

At the same time, airflow, used as a proxy for energy-related operation, affects the size and density of the visual elements. Higher volumes of pressurized air supplied to a space result in larger and more pronounced visual points, indicating greater energy demand. As comfort-

driven conditions intensify, the combined effects of color shift and growth produce visible withering, representing the rising energy cost of maintaining comfort rather than comfort as a positive state (See Figure 4.7).

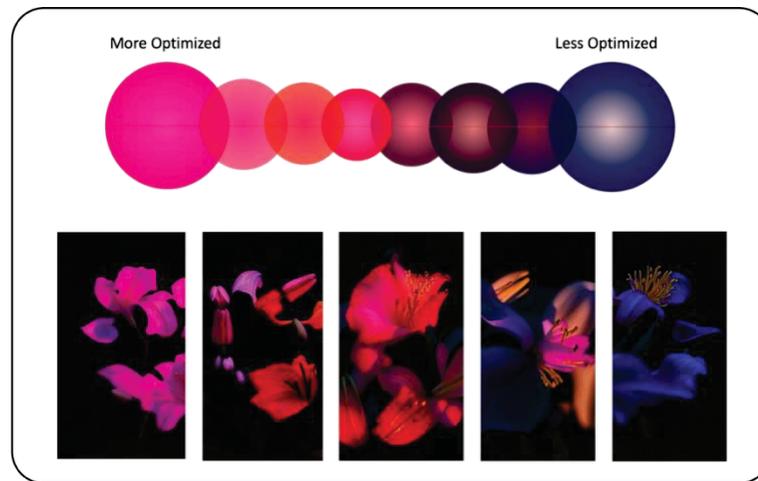


Figure 4.7 Floral sustainability color map: warm-to-cool palette encoding building sustainability index

It is important to note that the visual state of the flowers does not represent occupants' subjective comfort directly. Instead, it reflects the sustainability cost of maintaining comfort. In some situations, occupants may experience comfortable indoor conditions while the flowers appear withered, indicating that achieving this comfort required excessive energy use. All comfort and sustainability thresholds were embedded in the software and used to normalize incoming temperature and airflow data, which were then mapped to changes in flower color and scale to represent the energy effort required to maintain comfort.

The garden is shaped based on the library's floor plan, using 30 selected data points placed in individual rooms and open areas according to the BMS sensor layout. Each data point

influences the form around it, and together they create a collective image. When shapes overlap, their colors and forms interact and change (Figure 4.8).



Figure 4.8 Sensor layout of the library floor plan showing 30 selected data points. Each circle represents a sensor location

As shown in Figure 4.9, temperature rises steadily until midday before gradually decreasing, while airflow follows a smoother, more gradual increase throughout the day. These patterns directly influence the generative garden depicted in Figure 4.10. Early in the day, the garden appears fresh and vibrant, with smaller flower forms and warm, natural tones. As the temperature peaks around midday, the lilies begin to shift toward cooler tones and take on a duller appearance. In the afternoon, although the temperature slowly decreases, the continued increase in airflow contributes to subtle changes in size and movement within the garden's visual composition, as a result, when a zone trending away from sustainability. This means the garden's appearance is always changing. When the indoor environment thrives, nature responds.

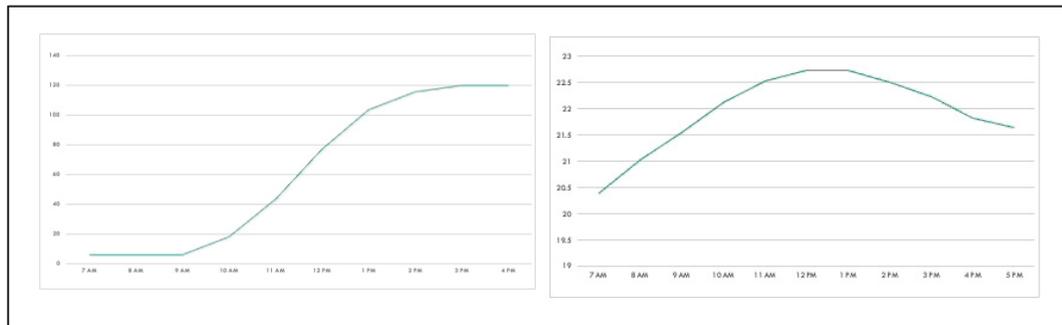


Figure 4.9 Temperature (right) and air flow (left) through the day

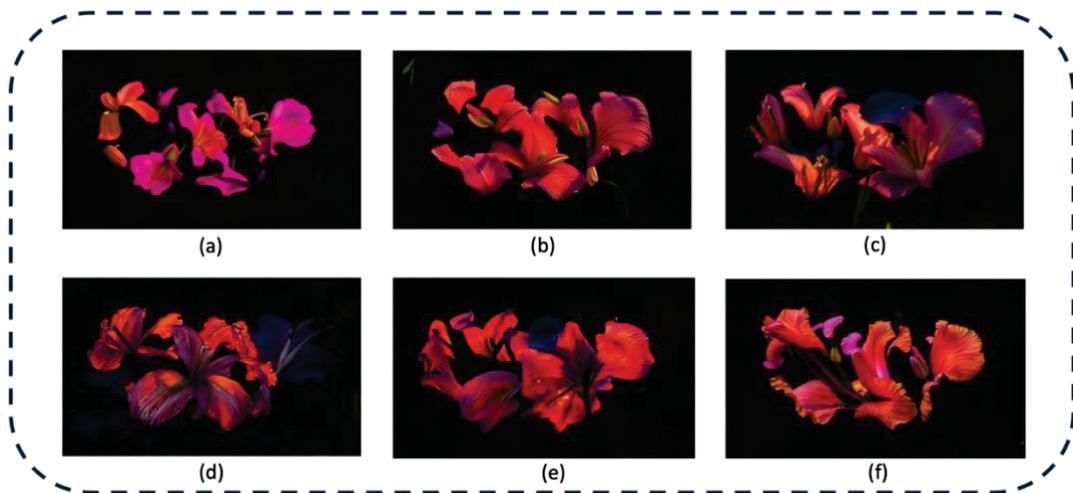


Figure 4.10 AI-generated lilies representing six timepoints during a typical day: (a)7:00 AM, (b)10:00 AM, (c)11:00 AM, (d)12:00 PM, (e)1:00 PM, and (f)4:00 PM

4.5 Evaluation

Based on the literature regarding the role of art in environmental communication and influencing pro-environmental behavior, we structured the evaluation of our installation. Given the intentions behind the *Garden of Sensors* and theories from environmental psychology and aesthetics, the installation aims to create a space for emotional engagement and reflection.

The evaluation was conducted using a questionnaire administered on site. Prior to participation, each participant received a brief verbal explanation of the project's intent and the meaning of the installation, ensuring a shared understanding of how the visual elements

related to building sustainability. To support this explanation, a poster describing the concept, a simplified technical dashboard was displayed near the installation. These materials provided contextual information about the data sources and the visual metaphors used, allowing participants to engage with the installation in an informed manner before responding to the questionnaire.

To assess the impact of the installation from multiple perspectives, the questionnaire was structured around several complementary dimensions: emotional engagement, cognitive reflection, and intention to act. In addition, contextual factors, including environmental engagement, prior experience with art, and sociodemographic characteristics (age, gender, and education), were incorporated to support interpretive analysis of participants' responses. These dimensions were distributed across different sections of the questionnaire to capture how affective, reflective, and contextual factors jointly shaped participants' experience of the installation. The following hypothesis guided our evaluation:

“Greater emotional (both positive and negative) and cognitive responses are expected to be positively associated with stronger pro-environmental behavioral intentions.”

4.5.1 Emotional factors

We evaluate the emotional engagement aspect by a mix of the theory of planned behavior alongside the Values-Beliefs-Norms theory (Stern et al., 1999). The Theory of Planned Behavior suggests that an individual's intent, shaped by attitudes, subjective norms, and perceived control, serves as a more reliable predictor of environmental behavior (Icek, 1991). Emotional experiences can shape attitudes by making the issue feel personally meaningful. By visualizing environmental data as a living, aesthetic system, the work aims to foster more meaningful and positive attitudes toward environmental responsibility. Since the installation was shown in a public space (e.g., a university library), it contributes to the social context where environmental awareness is normalized. People viewing it together may feel part of a shared concern or value system. Even though the work doesn't directly instruct behavior, it

raises awareness and shows that small fluctuations in energy consumption matter and encourages a sense that individual control and actions impact sustainability.

Emotional engagement plays a key role in influencing pro-environmental behavior, particularly when it evokes empathy, the ability to emotionally connect with the experience of others, including non-human life. Empathy fosters a sense of personal responsibility and care, both of which are essential to sustaining motivation for environmental action. This connection is evident in the work of artist Kassandra Bossell, who collaborated with ecologist Garry Daly to create an installation exploring human and non-human perspectives within local ecosystems. Their exhibition reportedly evoked feelings of wonder and empathy in thousands of visitors, many of whom expressed a stronger sense of responsibility for local ecology after engaging with the work (Curtis, 2020).

Garden of Sensors was designed to elicit both positive and negative emotions, as research shows that mixed emotions can encourage sustainable behavior (Brosch, 2021). The colorful garden created an aesthetically pleasing experience, while the vulnerability of the lilies and their withering, evoked deeper emotional resonance. To assess the emotional impact of the installation, participants were asked to select emotions that best represented their experience. The list of emotions was drawn from empirical aesthetics (Schindler et al., 2017; Silvia, 2009), moral emotion research in environmental psychology (Bamberg et al., 2007; Kals et al., 1999), and studies assessing responses to environmental art (Sommer et al., 2019). This blend allowed us to capture both reflective and motivational dimensions of affective engagement in response to the installation. We considered a list of emotions, both positive (Awe, Inspiration, Happiness, Hope) and negative (Guilt, Sadness, Melancholy, Helplessness), with “unaffected” included as a neutral state. Understanding the negative emotions is important given the cross-loading of items associated with feeling “moved” on this factor. Melancholy was included among the negative emotions because it tends to occur more frequently when individuals are in a negative mood. However, melancholy is a complex emotion. As noted by Schindler et al. (2017), sadness in aesthetic experiences can have a pleasurable quality, combining indulgent reflection with feelings of sadness, loneliness, and emptiness.

4.5.2 Cognitive factors

The cognitive factors are a mix of a few studies designed to evaluate reflections and reactions, assessed by asking participants, “To what extent do the following statements describe your experience with the Garden of Sensors?” and presenting multiple statements. Inspired by studies such as Sommer et al., we used a modified version tailored to our installation context, where statements like “This data representation made me reflect on resource consumption in this building” aimed to capture behavioral reflection, and “This data representation made me think about environmental problems” addressed broader environmental awareness.

Given that we selected a fragile, vulnerable local plant, we were particularly interested in evaluating whether the installation helped users connect to the local environment and biodiversity. This motivation is reflected in the statement “This data representation made me reflect on local ecosystems and biodiversity”, an approach informed by systems-aware thinking as described by Molderez & Ceulemans (2018). Systems thinking emphasizes seeing wholes rather than isolated parts and understanding how different elements influence each other within a broader context. Also, each sensor’s data not only determines its own visual output but also influences surrounding forms. The generative garden emerges from these interdependent relationships, illustrating how local environmental changes affect the broader ecosystem, visually and conceptually.

Statement 3 targeted psychological distance by situating the installation in the library, encouraging students and staff to see themselves reflected in the garden’s responses. The building and natural environment are no longer a distanced far concepts (Xu et al., 2020). If they don’t see themselves as part of it, they may not feel responsible. This integration diminishes psychological distance, fostering a sense of personal connection and responsibility toward environmental stewardship.

Also in statement 5, we emphasized individual responsibility and awareness of behavior through the prompts “This data representation helped me better understand how daily activities affect sustainability in this building” and “This data representation made me more aware of my behavior’s impact on the environment.”

4.5.3 Intentions

In the context of environmental behavior, emotional engagement can play a key role in forming personal values and shaping one's sense of environmental responsibility. This aligns not only with the attitude component of the Theory of Planned Behavior but also with the Value-Belief-Norm (VBN) theory, which emphasizes that values (especially biospheric and altruistic values) influence beliefs and personal norms, ultimately guiding behavioral intention (Ajzen, 1991; Icek, 1991; Stern et al., 1999).

We measured the behavioral intention and influence at the end of the questionnaire by asking two questions along with short nudges. First question is “Would you be willing to adjust your habits based on environmental insights, such as building performance data?” and “How likely are you to check building performance data (e.g., air quality, energy use) linked to your activities if it were easily available?” asks participants about their likelihood of engaging in a specific future action which falls under the Theory of Planned Behavior (Ajzen, 1991). It reflects perceived behavioral control and motivation.

To subtly encourage reflection and intention toward sustainability, certain survey questions included behavioral nudges, short framing prompts designed to guide participants toward pro-environmental thinking. Nelson et al., (2021) demonstrated that informational nudges, whether positively or negatively framed, can significantly influence environmentally responsible behavior without limiting individual choice. By framing a question with phrases such as “Research shows that small, consistent actions can have a big impact on sustainability,” and then forming the question “Would you be willing to adjust your habits based on environmental insights, such as building performance data?”, the goal was to create a low-pressure prompt that increases the salience of everyday behaviors. These kinds of nudges are effective because they raise awareness while preserving autonomy, encouraging respondents to consider the consequences of their choices in a subtle yet meaningful way.

4.5.4 Covariates

Covariates are usually defined as variables that may influence the outcome of interest. In this qualitative analysis, we treat them as contextual factors that help us interpret participants' emotional and reflective responses. Rather than controlling for them statistically, we use them to understand how different backgrounds might shape the way individuals experience the installation. We included two contextual factors: experience with art and environmental engagement. Experience with art was assessed using the self-evaluation scale from Sommer & Klöckner (2021), ranging from 1 ("I am an art lover and go to exhibitions regularly") to 5 ("I really dislike art and anything artistic"). This helps us interpret whether prior familiarity or interest in art influenced how participants described their reactions.

Environmental engagement was measured using a list of environmentally friendly activities to capture how involved participants already are in sustainable practices. This is relevant to the idea of "preaching to the choir," since people with stronger environmental awareness and habits may experience or articulate the installation's impact differently.

4.6 Results

The results are organized around the three interpretive dimensions: emotional engagement, cognitive reflection, and behavioral intention. Together, these findings provide insight into how participants responded to the Garden of Sensors installation and how different types of affective and cognitive reactions relate to pro-environmental intentions. Responses were analyzed qualitatively through thematic interpretation, focusing on recurring patterns across emotional engagement, cognitive reflection, and stated intentions.

4.6.1 Emotional Engagement

Among 43 participants, the most frequently reported emotions were inspiration and happiness, followed by optimistic feelings such as awe and hope. Reflective emotions such as guilt,

sadness and melancholy were less common, and Passive emotions like helplessness or feeling unaffected were rare. Figure 4.11 shows the frequency of each reported emotion, providing a more detailed view of participants' emotional engagement with the installation.

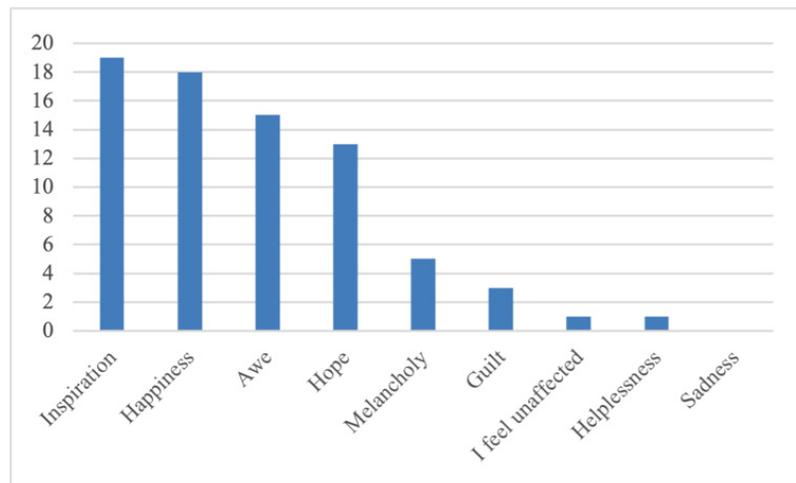


Figure 4.11 Frequency of each emotion selected by participants

4.6.2 Emotions and Pro-environmental Intentions

Participants who reported feeling inspired often described a greater openness to adjusting their habits or engaging with building performance data. Inspiration was frequently framed as energizing or motivating, and several participants linked this feeling to a personal desire to act more sustainably. In contrast, reflective emotions such as guilt, sadness, or melancholy tended to evoke introspection rather than action. When these emotions were mentioned, participants often spoke about environmental concern or personal responsibility, but this did not usually translate into explicit statements about changing behavior. These emotions appeared to heighten awareness without necessarily prompting concrete intention.

Vitality-related emotions (e.g., happiness) and passive emotions (e.g., feeling unaffected or helpless) were only weakly connected to discussions of future behavior. Participants

expressing these states rarely elaborated on environmental intentions, suggesting that these emotions played a limited role in motivating sustainable action.

Overall, uplifting, aspirational emotions, particularly inspiration and hope, were more commonly paired with statements about willingness to adjust habits or engage with environmental information. Heavier, reflective emotions were more associated with contemplation and emotional resonance than with behavioral intention.

Participants also had the option to describe additional emotions beyond the predefined list. These included terms such as calmness, feeling impressed, beauty, curiosity, relaxation, and joy. These responses show that the installation evoked a broad range of affective states, extending from reflective moods to gentle vitality-based feelings.

4.6.3 Cognitive Reflection

Participants generally expressed a high level of cognitive reflection in response to the installation. The strongest theme concerned daily life relevance, with many participants describing how the visualized data prompted them to think about their own routines, comfort, or energy use. This suggests that the installation was particularly effective at linking environmental insights to participants' personal habits.

Themes related to ascription of responsibility and environmental awareness also emerged frequently. Participants often acknowledged their role in environmental impact or reflected on broader issues such as energy consumption and sustainability. Awareness of consequences appeared as a recurring but less pronounced theme, indicating that while participants recognized environmental impacts, they did not always articulate direct cause-and-effect links (Figure 4.12).

The least developed theme was systems thinking. Few participants discussed wider ecological or infrastructural connections, suggesting that the installation more strongly supported personal and immediate reflections rather than abstract or systemic ones.

Across accounts, all forms of cognitive reflection were described in ways that aligned with pro-environmental intentions. Participants who reflected on personal responsibility or daily life relevance were more likely to mention small changes they might make or a heightened interest in environmental information. This suggests that reflective engagement, particularly when tied to personal routines, can support the emergence of environmentally oriented intentions.

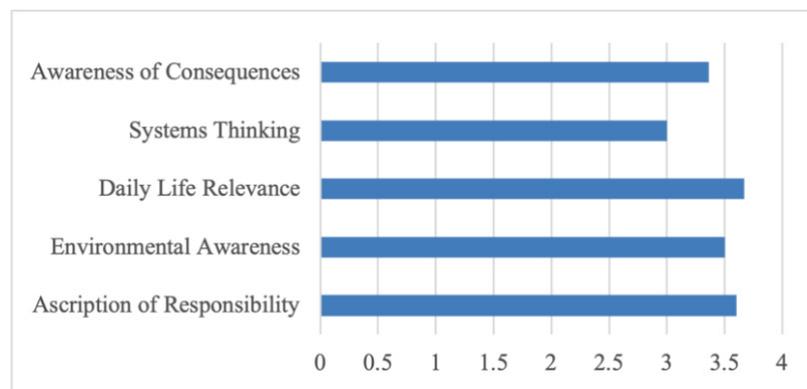


Figure 4.12 Frequency of each cognitive category selected by participants

4.6.4 Cognition and Emotion

We observed that emotional responses and cognitive reflections were closely interconnected. To explore this relationship in more depth, we examined how participants described their emotions alongside the five cognitive themes. Inspiration and hope appeared most consistently linked to reflective thinking. Participants who reported feeling inspired often described a stronger sense of personal responsibility and a clearer connection to their daily habits. In

contrast, participants who mentioned hope tended to reflect more on environmental consequences and broader environmental issues.

4.6.5 Sociodemographic and Covariate Contributions

To understand how participants' backgrounds might shape their experiences, we examined the role of gender, education, environmental engagement, and prior art experience as contextual factors. Rather than treating these characteristics as predictors, we examined how they appeared to shape participants' interpretations of the installation.

Sociodemographic covariates, including education, played a limited role in shaping participants' responses. Prior environmental engagement and art experience occasionally influenced how participants framed their reflections, but these factors did not substantially alter the overall emotional or cognitive patterns observed. Gender did not appear to meaningfully differentiate participants' responses. Overall, while background characteristics shaped the interpretive lens through which participants approached the installation, they did not fundamentally change the types of emotions or reflections expressed.

4.7 Discussion

This study aimed to propose a method promoting pro-environmental thinking and potential behavior change among smart-building users. The Garden of Sensors installation transformed building sustainability and comfort data into an aesthetic experience through generative design and artificial intelligence. Unlike traditional dashboards or analytical feedback systems, this form of data representation engaged participants simultaneously on emotional and cognitive levels. The installation was presented in the university library, and participant responses were collected through a questionnaire guided by insights from environmental psychology and aesthetics.

The findings suggest that the installation was effective in triggering emotional engagement, cognitive reflection, and expressions of pro-environmental intention. Most participants described experiences that were reflective, perspective-expanding, or motivating rather than indifferent or defensive. However, the study cannot determine whether expressed intentions translated into sustained behavioral change, as no follow-up behavior was measured. This limitation connects to the well-known value–action gap (Kollmuss & Agyeman, 2002), highlighting the need for additional measures to support the translation of intentions into action.

A key theme emerging from the qualitative analysis is the role of aspirational emotions, particularly inspiration and hope. Participants who reported feeling inspired more often described a willingness to adjust their habits or explore environmental information. Hope also appeared alongside deeper reflections about environmental issues. Conversely, heavier reflective emotions such as guilt or melancholy tended to evoke introspection without being accompanied by clear statements about behavioral intention. This supports the broader idea that the quality of an emotional state matters: uplifting emotions seemed more conducive to constructive engagement, while negative or purely pleasant emotions did not have the same motivational traction. For example, participants who felt simply “happy” often appeared satisfied with the environment, which may have reduced the need for further reflection, consistent with prior findings that positive affect can sometimes dampen analytical processing (Bless et al., 1990; Sommer et al., 2019).

Beyond emotional reactions, participants demonstrated a high level of cognitive reflection. The strongest themes were daily life relevance and ascription of responsibility, suggesting that the installation helped participants connect environmental information to their own routines and sense of accountability. Those who reflected on these aspects were more likely to describe potential changes to their habits. In contrast, themes such as ecosystem connection and systems thinking were less commonly expressed, indicating that while the installation facilitated personal relevance, it was less likely to prompt reflections on broader or more complex systems.

The interplay between emotion and cognition was especially notable. Inspiration often accompanied reflections about personal responsibility or the relevance of environmental data to everyday life, whereas hope tended to appear with reflections about environmental consequences or broader environmental concerns. This aligns with the view that emotions serve as an initial motivational spark that draws attention, while cognitive processes help contextualize and deepen that engagement (Brosch, 2021; Frijda & Mesquita, 1998; Gifford, 2014).

Sociodemographic covariates, including education, played a limited interpretive role. While prior environmental engagement or art experience occasionally shaped how participants framed their reflections, these factors did not meaningfully alter the emotional or cognitive patterns observed.

It is important to acknowledge that generative AI models, such as the stable diffusion model used to create visual elements in this research, have an environmental cost due to energy use during training and inference. Research on AI energy consumption highlights the need for transparency when deploying these technologies (Strubell et al., 2019; Bender et al., 2021). However, the generative AI component relied on a pretrained model and limited inference, resulting in modest energy use that was justified by the research and educational purpose of the installation.

Overall, this study demonstrates that aesthetic data representations can meaningfully elicit emotional and reflective engagement with environmental information. The prominence of inspiration, hope, and personal-relevance reflections suggests that such installations may be most effective when they evoke uplifting emotions and emphasize the connection between environmental data and users' daily lives.

4.8 Conclusion

The purpose of this study was to develop a methodological framework to effectively promote sustainable behavior in buildings through design. Rather than directly prompting immediate behavioral change, the installation operated as an affective catalyst, an experience that invited participants to pause, feel, and think. The findings suggest that intentions, feelings, and reflections were closely intertwined. Emotions alone did not determine pro-environmental intention, nor did cognition on its own. Instead, emotions appeared to ignite initial engagement, while cognitive reflection helped anchor that engagement in personal meaning and responsibility. By translating abstract environmental indicators into a sensory and emotional experience, the installation served as a perceptual interface that opened space for intention formation. This aligns with perspectives in environmental psychology that highlight the interplay between affect and cognition in motivating long-term environmental engagement (Bamberg & Möser, 2007; Gifford, 2014; Brosch, 2021).

Despite participants expressing willingness to adjust daily routines or consult building performance data, self-reported intentions cannot verify long-term behavioral change. The well-documented value–action gap reminds us that sustainable behavior requires more than initial motivation. Future interventions may benefit from combining artistic installations with supportive organizational structures and participatory engagement.

This study offers contributions to both artistic practice and scientific inquiry. Artistically, it advances (1) the situated use of building-specific data in environmental art and (2) the emotional and symbolic transformation of environmental information through generative AI. Scientifically, it contributes to a qualitative examination of the affective and reflective processes underlying expressions of pro-environmental intention. In contrast to approaches centered on information delivery or aesthetic appreciation alone, this work highlights a multisensory, psychologically informed pathway to sustainability engagement.

Several limitations should be acknowledged. First, direct measurements of energy consumption were not available. Instead, ventilation airflow data were used as an operational

proxy for energy-related system activity. While airflow is closely linked to HVAC energy demand, particularly during heating periods, it does not capture total energy use and therefore provides only an approximate representation of energy-related sustainability costs. Second, the comfort thresholds implemented in the system were based on generalized BMS standards and did not incorporate direct occupant feedback, which limits their ability to consider the individual comfort perceptions. The sample size was relatively small, relied on self-reported perceptions, and was situated within a specific institutional setting (a university library). A further limitation of this study is the absence of direct collaboration with a professional visual artist during the design process. While artistic input was considered during the conceptual phase, practical constraints prevented interdisciplinary collaboration. Future work should explore repeated exposure and compare results across cultural and organizational contexts. Enhancing interpretability through multimodal or numerical overlays may also deepen users' understanding and support stronger links between emotional engagement and sustained pro-environmental behavior.

4.9 Acknowledgements

The authors would like to thank the Technical Services, the Real Estate Asset Management Office, and the Sustainable Development Office of ÉTS for providing access to environmental sensor data and supporting the installation of *The Garden of Sensors*. We also extend our gratitude to the ÉTS University Library for their continuous support in organizing the event. Heartfelt thanks to the participants who engaged with the installation and generously shared their reflections. Special thanks to the interdisciplinary collaborators who contributed to both the artistic and technical development of the work. Generative artificial intelligence tools were used for the refinement and clarification of the written text, which was after that attentively checked or edited to make sure that the initial meaning was conserved.

4.10 Declaration of Interest Statement

The authors declare no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The Bibliography section is presented at the very end of the thesis.

CONCLUSION

This thesis set out to explore how a data-driven generative installation can bridge the gap between smart building technologies and users' environmental engagement. Two research objectives guided this work. The first objective was to identify an approach capable of presenting building performance data in a more sensible and impactful way in order to foster pro-environmental behavior among occupants. The second objective was to investigate how environmental art could be implemented as a medium to communicate building data through emotional engagement and empathy.

Regarding the first objective, the work demonstrated that data produced by automated building systems can become more than a technical artifact; it can function as a medium for aesthetic, emotional, and moral reflection. By transforming building performance data into a visual and sensory experience, the *Garden of Sensors* installation encouraged users to perceive the building as a dynamic, responsive system and to recognize their place and responsibility within it.

Guided by the Design Science Research (DSR) framework, the second objective was achieved through: a replicable methodology for converting building system's data into generative art, and an empirical qualitative assessment of how emotional and cognitive processes interact to shape pro-environmental intention. While the broader question of whether environmental art can directly produce behavioral change remains unresolved, the findings show that data-driven environmental art can meaningfully influence perception, reflection, and willingness to act. Users, regardless of technical background, engaged with the installation in ways that deepened their understanding of building performance and environmental implications.

Beyond this specific case, the work illustrates the broader potential of interdisciplinary, artistically informed strategies for humanizing data and fostering environmental literacy in everyday environments. These approaches invite occupants to relate to buildings not only through dashboards or efficiency metrics but through affective and experiential encounters that cultivate awareness and care. Future research could extend this work by incorporating

longitudinal behavioral tracking, participatory collaboration with artists and occupants, or adaptive feedback systems that reinforce sustained action. As digital infrastructures increasingly mediate relationships between people and their environments, reintroducing aesthetic and emotional dimensions offers a compelling pathway for reconnecting individuals with the ecological realities embedded in their data.

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