

Article

# Activating Data through Eco-Didactic Design in the Public Realm: Enabling Sustainable Development in Cities

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**Abstract:** This paper explores how design in the public realm can integrate city data to help disseminate the information embedded within it and provide urban opportunities for knowledge exchange. The hypothesis is that such art and design practices in public spaces, as places of knowledge exchange, may enable more sustainable communities and cities through the visualization of data. To achieve this, we developed a methodology to compare various design approaches for integrating three main elements in public-space design projects: city data, specific issues of sustainability, and varying methods for activating the data. To test this methodology, we applied it to a pedogeological project where students were required to render city data visible. We analyze the proposals presented by the young designers to understand their approaches to design, data, and education. We study how they “educate” and “dialogue” with the community about sustainable issues. Specifically, the research attempts to answer the following questions: (1) How can we use data in the design of public spaces as a means for sustainability knowledge exchange in the city? (2) How can community-based design contribute to innovative data collection and dissemination for advancing sustainability in the city? (3) What are the overlaps between the projects’ intended impacts and the 17 United Nations Sustainable Development Goals (SDGs)? Our findings suggest that there is a need for such creative practices, as they make information available to the community, using unconventional methods. Furthermore, more research is needed to better understand the short- and long-term outcomes of these works in the public realm.

**Keywords:** eco-design; eco-art; open data; eco-didacticism; art and design practices; public art and design; urban installations; raising awareness; sustainable development; sustainable cities



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## 1. Introduction

Sustainability is often perceived within the context of crisis management, under the umbrella of urgent challenges. However, this “crisis” mode may also inhibit collective thought and social change since it can remain broad in scope and focused on the present. In turn, it can immobilize the general community and leave these programs in the purview of the “experts”, as investigated by Collins and Evans [1], and elaborated upon in the context of sustainability by the authors [2]. No matter how green our urban infrastructure is, one of the most difficult challenges in greening a city is to activate the collective intelligence [3] of unsustainable human and organizational practices and the social structures needed to make these shifts possible. We observe that effective action is slow to materialize, as collective knowledge and behavior change are part of a larger dynamic that requires understanding to reach a deep political and societal mindset.

If we consider collective civic intelligence, we cannot ignore the urban public realm as a key space for knowledge exchange. We also see that public spaces are increasingly

being used to exchange knowledge with the community [4–6]. At the same time, data are central in the discourse of sustainability; data are often perceived as a need for monitoring, a guide for action, and a means for evaluation [7]. However, how can design in the public realm activate data to spark collective civic intelligence and even action?

This paper explores how design in the public realm can integrate urban data to help exchange knowledge and enable a more sustainable community. Our hypothesis rests on the notion that sustainability in the city can be enabled through the visualization of data in public spaces, as these are essentially places of knowledge exchange. To achieve this, we develop a comparative methodology to understand the various design approaches to integrate data, design, and sustainability in public-space projects.

We used the work completed in a classroom setting by a group of students of sustainable design to test the methodology and draw some insights into the approaches that emerged. The objective of this pedagogical project was for the students to explore how they can activate data through design, which can also “educate” the community about sustainable issues. This pedagogical approach for teaching sustainable design was intended to produce a variety of ideas for the public realm that would activate open data collected by the city that most often remain hidden and not accessible to most people. These open data represent a series of issues for the city, and this design exercise aims to render visible the invisibility of the significance of these data. The pedagogical project focused on all these issues and therefore was considered as the best case to test our hypothesis.

Thus, our research aims to investigate how collecting and disseminating data in the public realm through design can address the different domains of sustainability (namely, the social, economic, environmental, and cultural) while also raising awareness or soliciting action. We extend our analysis to understand how the different projects relate to the United Nations Sustainable Development Goals (UN SDGs). Specifically, the research attempts to answer the following questions:

- How can we use data in the design of public spaces as a means for sustainability knowledge exchange in the city?
- How can community-based design contribute to innovative data collection and dissemination for advancing sustainability in the city?
- What are the overlaps between the projects’ intended impacts and the 17 SDGs?

To answer these questions, we start by presenting the main literature concerning the role of design in enabling sustainability and extract the tensions that define the design process—in terms of data, design outcome and objective, mode of delivery, and sustainable development impact. We then present the resulting methodology that we propose for studying and comparing the urban public-space projects. In the third part, we present the specific case study used to test the methodology. Before concluding our study, we reflect on (1) how the method enables us to develop our understanding of sustainable design in the public realm, (2) any gaps in the analysis, and (3) if there is a common thread in the design approaches of these projects. While previous publications have studied each of these elements independently, no previous research has attempted to explore their synergistic outcome within a design-based research approach, deciphering the tensions that guide projects’ design process or their overlaps with the SDGs.

## 2. Sustainability, the Community, and the Design of Public Spaces

### 2.1. *Design in the Public Realm as a Means for Communicating and Enabling Sustainability*

In the 1960s, green design represented a major shift for designers, embedded in the aspiration of eco-awareness, driven by a radical approach that questioned the emerging conspicuous consumption phenomena and the poor state of the urban condition [8–11]. During this time, some architects and designers even lived in their structures to express their connection with nature [7]. The didactic efforts of the 1960s seem to be founded on a vastly different set of motivations from those of modern green design [12,13]. Today, green design seems to be aiming for the recognizability of eco-features [14], as a means to engage with the community and to demonstrate eco-responsibility.

The ability to communicate eco-responsibility is seen as a growing phenomenon [15,16]. A rise in the occurrence of discernible eco-features in the design of the city—its buildings and public spaces—has occurred in the past few decades, which may contribute to this [6,17–22]. In this emerging phenomenon, projects are not only designed to *be* eco-efficient, but they are also designed to *appear* eco-efficient [23].

The phenomenon of embedding messages in art and design practices is not new. Indeed, art and design in the public realm can convey messages to the general population, rather than just the patrons of art institutions, such as a museum. These practices may also have the capacity to contribute to emergent critical discourses [24]. Increasingly, public art and design have sought to espouse messages of environmental degradation [18]. The basic premise of this type of public art and design, which aims to synthesize concerns of sustainability, is to enable collective awareness [22]. As early as 1995, Suzanne Lacy described this new genre of public art as work that can contribute to the common good when inserted in the public sphere [5], to a point of becoming a political act [4]. It has also been suggested that open creative practices on a macro level can spur societal innovation [25].

In a recent publication, Cucuzzella et al. refer to this phenomenon as an eco-didactic approach [26]. These authors have defined the eco-didactic approach as “a new mode of seeking public enlightenment through the arts, [which] ties the creative and design fields to a form of instrumentality” [26]. We propose that eco-didacticism in the public realm can be characterized by spaces that are designed to deliver an eco-message through expressive, informative, and educative means.

One characteristic of eco-didacticism is the desire to inform viewers of a project’s green qualities by encouraging them to think about its physical and connotative features. Cucuzzella et al. [26] refer to this as a *cognitive experience*. This implies that some of the eco-features must be made visibly obvious to visitors in order to deliver clear and uncontestable information through *formal qualities*. This requires a *communication approach* for disseminating the desired message based on collective consensus. It is possible to identify characteristics that are not only eco-features attesting to resource performance but also explicitly seeking to *exhibit* these features to visitors.

In the next few paragraphs, we provide a brief introduction to the three main areas that are key in the process of designing installations in the public realm, which incorporate data for communicating issues of sustainability with the community. These are data collected by the city, the broad imperatives of sustainability for the smart city, and the UN SDGs as a potential metric.

## 2.2. Data in the City

Today, data are increasingly perceived as an object of design—where the objective is to find innovative approaches to either communicate existing city data or collect new forms of data. Data in the built environment have been used for a variety of means. For example, they have been used as a feedback mechanism for responsive environments to better manage urban operations and resources [27]. Furthermore, the collection, sharing, analysis, and availability of data have been recognized as a critical means for tracking and, in turn, achieving sustainable development goals [28]. This practice highlights that data, while being a managerial necessity, allow for novel connections with citizens [29]. As such, we increasingly see data being used to exchange knowledge with the community, either through phone applications or through digital or interactive devices placed throughout the city.

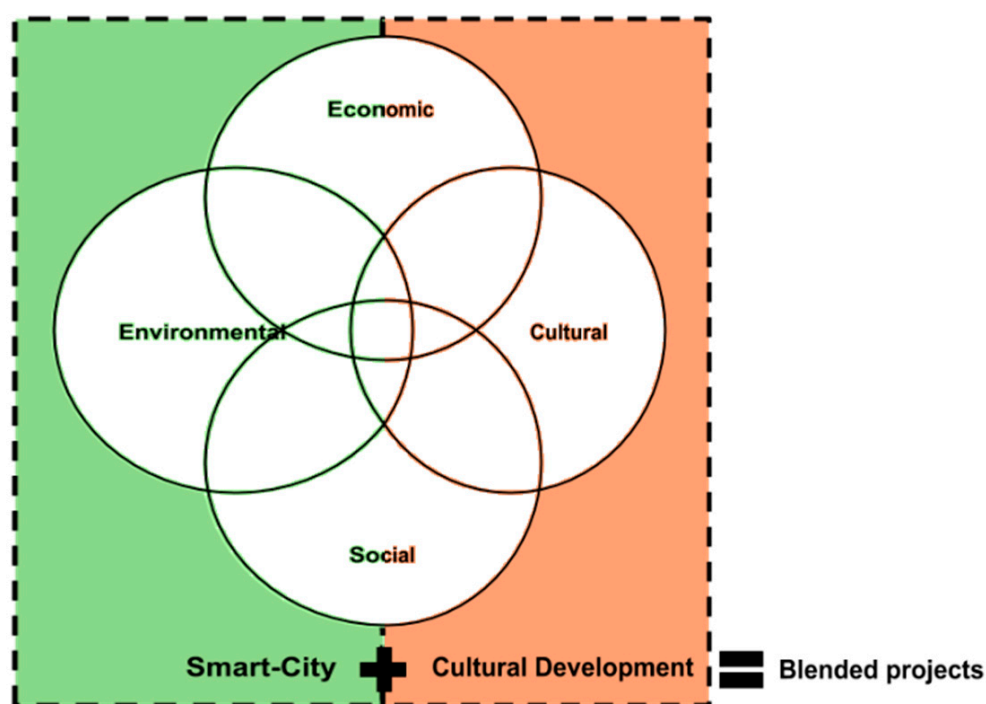
However, data can only be operationalized when coupled with effective information and communication technology (ICT). The application of new technologies combined with ICT has been viewed as a cornerstone for smart development [30], for improving monitoring and for building knowledge [31], and for democratizing growth, ensuring equal access, and encouraging participatory action [32,33]. Communicating data to urban citizens and users of interior or public spaces has been shown as an effective way to inform

actions and, in many cases, even change behaviors. This can be applied to energy actions, for example [34–36].

### 2.3. Sustainability and the Smart City

Antoine Picon has recognized that a smart city contains digital tools that allow the optimization of its functioning and sustainability goals [3]. Picon states that the smart city is inspired by a deliberately technocratic emphasis, with its programmed monitoring and effective management. This author claims that these tools can also address the quality of life of inhabitants, as well as the types of relationships they maintain with one another. Thus, a connected and collaborative city may initially seem opposed to the smart city, but the two are mutually complementary. This is because the smart city sets out to reinvent collaborative citizen experiences spontaneously—where collective experiences can help envision and embody positive futures [3]. These experiences would be nourished by, and ultimately contribute to, both the human and hard sciences. Bisello et al. [37] propose that smart and intelligent cities are encapsulated by the sustainable city vision—where the social, economic, environmental, and cultural dimensions are in balance.

Rethinking the urban design project that aims to further the sustainable goals of a city, in a previous publication, we [38] define a “blended project” as a theoretical framework that addresses sustainability and smart cities’ concerns at once through cultural developments (Figure 1). In this research, we propose that blended projects can accomplish a multitude of outcomes: (1) They are well integrated within their context; (2) they can effectively manage natural and energy resources; (3) they can improve the quality of life; (4) they can encourage local culture production; and (5), most importantly, they are activated and programmed. These types of projects are also appropriate to their users and environmentally sound. Thus, blended infrastructure projects are means for a sustainable vision that can also generate a unified brand (i.e., the city as destination) and present a sense of place that is unique, tangible, and relevant [39]. Figure 1 illustrates the relationship between smart-city and cultural development strategies through the lens of sustainability, in which their sum is the potential for blended projects.



**Figure 1.** The relations between the sustainability pillars (two approaches to urban renewal: smart city + cultural development and the resulting blended project) (Cucuzzella and Goubran [38]).



This current research considers public blended urban design projects as potential enablers for environmental, social, cultural, and economic sustainability. This can be achieved through “the intrinsic links between cultural diversity and biodiversity, through its influence on consumption patterns, and through its contribution to sustainable environmental management practices as a result of local and traditional knowledge” [40]. It is important to note that the intersecting boundaries of Figure 1 are figurative in their definition, considering the complex reality of urban projects described by Dovey and Ristic [41]. Even projects that adopt a predominantly smart-city approach will inevitably include some cultural development aspects. Although these complex and intertwined relations cannot be ignored or reduced to single labels, they are approached and categorized in this paper based on the designers’ implicit intentions.

#### 2.4. The United Nations Sustainable Development Goals (SDGs)

The UN’s 2030 Agenda, approved in late 2015, marked an important shift in the global sustainable development effort [42,43]. Structured around 17 transformative goals, the SDGs and their list of clear targets are expansive and comprehensive (Jayasooria, 2016). Unlike previous sustainable development agendas, the SDGs are accompanied by a global call to action, offering a stable definition for sustainable development that designers can seek in their work—essential for infrastructure, design, and construction [44–48].

Today, the SDGs are becoming an essential tool for guiding public and private sustainability efforts. This is also the case in space design and architecture, as seen by the SDG architecture guides published recently [49]. Within the scope of this research, both “data” and “cities” are considered cornerstones for achieving the agenda’s targets. The role of ICTs’ for enabling development has made it the focus of several SDGs targets [50]. In their review of ICT’s role in the 2030 Agenda, Tjoa and Tjoa [51] propose that, while expanded technological infrastructure and usage might result in environmental drawbacks, ICTs enable unprecedented development capacities. This includes information access, supply chain management and integration, crowdsourcing of data (regarding health, well-being, and finance), and predicting and controlling disasters (such as in pandemic, as seen in Grantz et al. [52]). Recent research, such as that of Kostoska and Kocarev [53], highlights ways that ICTs can better align with the agenda goals by adopting holistic approaches integrating knowledge from the governance, sustainability, and data sciences.

Researchers have also explored the roles of cities and urban environments in achieving the SDGs. We already found that more than 40% of the agenda’s targets are dependent on construction and real estate activities (understood as designing, building, maintaining buildings, and infrastructure), and that those activities can directly affect sustainable development goals [54]. Researchers have also found that the SDGs and their indicators can provide a more balanced and integrated approach for applying urban sustainability principles and monitoring progress towards sustainable development [55,56]. However, their local application (i.e., in an individual project or a specific urban context) has proved to be challenging due to their generic characteristics, global focus, and the many topics they cover [57]. Consequently, developing methodologies and frameworks for integrating the SDGs in the design and analysis processes of projects is key for meaningful integration. This was attempted in available publications such as [58–61].

Against this backdrop, designers have a crucial role in exploring and materializing the links between their work and the 2030 Agenda. The authors have previously [58] suggested that this process has to happen in the early design stages—to ensure that the SDGs are embedded in the designers’ and their project’s intentions [62,63]. In this research, understanding the overlaps between the intents of city-focused design projects and SDGs can reveal the potential contributions of city elements to global sustainable efforts.

### 3. The Tensions Defining Urban Project Design

Given the above three areas of research, which, when considered together, may contribute to more sustainable cities, we describe in the next subsections the series of tensions

to consider when designing for sustainability, particularly when aiming to communicate a message to the general public, using data. The first series of tensions is represented by the imperatives of the four pillars of sustainability. Design projects often focus on one of these domains, while aiming to address the others without compromise. This is a difficult balance. We have also organized the four categories of tensions, defining the project design process as (1) the direction of the data exchange, (2) the design impetus (or motivation for its existence), (3) the mode of delivery of the message it seeks to convey, and (4) the sustainable development impact (SD Impact). Table 1, at the end of this section, presents a summary of these tensions with their associated references.

### 3.1. *Defining the Four Domains of Sustainability for Design Projects in the City*

#### 3.1.1. Environmental

We refer to the environmental project as one that addresses ecological issues or one that increases public or individual awareness of ecological sustainability on a city scale. These projects aim to reduce environmental impacts by reducing resource consumption or toxic emissions in the environment [64]. The design approaches adopted are often based on solving problems and limit their scope to areas of known environmental risk [65]. Although some projects seek solutions at the building, neighborhood, or even city scales, the impacts emanating from these built projects affect the whole ecosystem. Indeed, UNESCO has placed environmental sustainability at the core of its work and actions [66]. Its four main goals are as follows: establishing a certified Environmental Management System, reducing carbon emissions, eliminating single-use plastics, protecting biodiversity, and promoting urban agriculture. Such design projects aim to improve ecosystems.

#### 3.1.2. Social

Barron and Gauntlett [67] describe social sustainability as a system or structure that actively supports future generations' capacity to create healthy and livable communities. Socially sustainable communities are equitable, diverse, connected, and democratic. They provide a good quality of life. Besides this, other elements can include the following: the generally acknowledged values of discipline, honesty, and laws; and the unity of the community, comity, compassion, forbearance, fellowship, fraternity, diversity, humility, sodality, tolerance, patience, love, institutions and pluralism, etc. [68]. According to Polese and Stren [69], policies necessary for social sustainability require a more equitable fiscal situation, the integration of all communities within the city into a cohesive whole, and the provision of equitable mobility systems for access to public services and workplaces, all within the framework of an open and democratic local governing structure. A design project can be considered within the social domain when it aims to strengthen regional and vernacular connections and support communities to achieve an equitable and dynamic society.

#### 3.1.3. Economic

Theories in economic sustainability focus on the efficient usage and fair distribution of goods [68]. Thus, economic sustainability can be understood as a group of practices that will support economic growth without hindering a specific community's environmental, social, or cultural capacity. One possible approach here is to strengthen or even enable entrepreneurial opportunities, directly affecting economic growth [70]. Another example can include offering individuals price incentives for local products or services. These types of services may also have beneficial rebound effects. In this particular example, this service can also raise awareness about resource consumption and help prevent damage to the national economy. A design project can be considered within the economic sustainability domain when it aims to strengthen individuals' or communities' economic aspects.

### 3.1.4. Cultural

Grodach and Loukaitou-Sideris [70] define sustainable cultural projects as those that seek to create a positive city image, improve the quality of life, focus on community development, and encourage the local production of culture through arts and education. However, the cultural pillar of sustainability can be broad. The UNESCO “Global Report on Culture for Sustainable Cities, Culture: Urban Future” highlights the following:

“Culture and development have long had a reciprocal and interdependent relationship, although this has only gained momentum at the international level over the past 30 years. The evolution of holistic approaches is intrinsically linked with global debates, in particular those around the concept of sustainability” [71] (p. 18).

Furthermore, urban design projects in the city can specifically aim to sensitize the community about aspects of sustainability issues. This phenomenon is increasing, as we see more art and design projects that aim to place eco-messages directly in the public realm [26]. Thus, a project can be thought to address the cultural pillar when it aims to increase awareness about cultural issues in society.

### 3.2. Data Exchange Direction

#### Collection vs. Dissemination

Within “big-data” exchange processes, there is always a tension between the collection and the dissemination of information [72]. In sustainability science and citizen data, this tension is usually named the data pull and push process [73]. In many cases, the collection and dissemination have to happen in parallel or with a balance, where the applications usually involve “stakeholders needing to have access to real-time generated data sets and analytics from populations as large as a metropolitan community and be able to respond to as well as disseminate information to these populations” [74]. What is essential is that the collection (pull) or dissemination (push) of data might depend extensively on the context and development-problem area of focus [75–77]. In the context of design for enabling sustainability in the city, it is important to analyze the application or design’s primary function—oscillating between the collection or dissemination of data and information.

### 3.3. Design Impetus

#### 3.3.1. New Artefact vs. Product Augmentation

The definition of a new product or artifact can be considered a hierarchical combination of elementary subsystems where each of these subsystems is dedicated to consumers’ satisfaction and expectation [78]. As Lancaster [79] first suggested, a product may be conceptualized as a basket of attributes (physical and symbolic) that seek to satisfy consumers’ needs. Innovation may classify the idea as “new” and a radical shift from its precedents if any. There are two main criteria for innovation: the degree of novelty and the novelty’s nature [78]. According to these authors, a product can be thought of as a composition of technical subsystems and linking mechanisms. Linking mechanisms refer to how the new subsystems can be integrated within the new product: Is the linkage completely different from the previous version? Based on this, it is possible to distinguish between modular innovations and architectural innovations. A modular innovation changes the subsystems without changing how they are linked. An architectural innovation imposes a change in the links that unite the subsystems. As such, we can think of design as proposing entirely new artifacts or presenting improvements, or augmentations, for existing products.

#### 3.3.2. Product vs. System

In this tension, we considered whether the project proposed was the design of an artifact (a technical problem) or if the design considered the system within which it existed and sought to address this larger complexity of its environment (a combined technical, social and cultural problematic) [80]. The main difference between a product and system approach is that the system-focused design pays attention to the relationships that the

new artifact has with the other elements in its context and how these other interconnected elements are influenced by this new design [81–83]. If a product is focused on questions of affordances [84], efficiency [85], or even aesthetics [41], then the product is embedding itself within a system. In this case, it is addressing these qualities while aiming to understand the dynamics of the new artifact within the larger context in which it lives [86–88]. Therefore, a “system focus” would entail a comprehension and articulation of the dynamics, influences, or impacts of the new artifact with its environment. Whereas a “product focus” does not consider its wider influences or impacts, and remains purely technical.

### 3.4. Mode of Message Delivery

#### 3.4.1. Physical vs. Virtual Approach

Increasingly, societies and humans interact within the digital world [89]. A connected society enables greater socialization while remaining contactless, living in the virtual [3]. A virtual mode of message delivery would entail an artifact that lives in the digital world, enabling a message to be delivered through the means of the connected city [29]. On the other hand, a physical artifact in this research project is defined as one that is materially embedded in the public realm [22], where the general public can experience it through their physical senses. An example of a physical artwork in the public realm is Ice-Watch, an artwork exhibited at COP21 in Paris, a 2015 United Nations Conference on Climate Change. This famous public space artwork was created by artists Olafur Eliasson and Minik Rosing. It was an intervention in the very physical city, as spectators often are photographed touching the melting blocks of ice standing idly in the public realm. However, thousands of people were affected by this piece without ever visiting the actual site in Paris, and the other cities in which the artwork was exhibited. They discovered the artifact through its accompanying website, as well as through the media that poured out after each installation. So, even if Ice-Watch was a very physical installation, its virtual presence and associated press helped it touch communities worldwide [90]. This public-space installation is therefore adopting both a physical and virtual approach.

#### 3.4.2. Consensus vs. Dissensus

Communicating eco-messages can happen in a multitude of ways. If we consider Habermas’s theory of communicative action, we see that the most substantial arguments encapsulate elements of objectivity, subjectivity, and normativity [91,92]. Specifically, the communication approach of the intended message of an eco-didactic work can span from one that is universally accepted (using the conceptual model of consensus) to one more subtle, or even subversive (using the conceptual model of dissensus) [93,94]. When communicative actions are conveyed, not through words, but physical or virtual artifacts, then the three dimensions of the communicative action must be considered a little differently. For example, the readability of the message and who is “allowed” to read it produces an additional political dimension for the work [95].

An example that would illustrate the difference between consensus and dissensus as a method for the mode of message delivery is the work by Wolf Vostell. His work, which depicts a car made out of concrete placed in the public realm, critiques the ubiquitous use of the automobile. This is an example of how public art can deliver a message that is already well understood in the community (consensus), yet also provides a visceral experience.

### 3.5. Sustainable Development Impact

#### 3.5.1. People vs. Planet

The development of products inevitably places the burden of environmental degradation on individuals rather than corporations. Humans feel the brunt of the responsibility for the planet’s degradation, yet corporations are the main culprit [96]. Taylor and Watts state that “20 fossil fuel companies whose relentless exploitation of the world’s oil, gas and coal reserves can be directly linked to more than one-third of all greenhouse gas emissions in the modern era” [96] (p. 1). Given that the increasing impacts of human activity on

the environment on all scales have outpaced the systems and processes of the natural environment, humans are equally increasingly striving to find innovative ways to address this imbalance [97]. As innovations in new materials, new technologies, and omnipresent data are increasingly seen as the foundation of the city's future, there arises an associated distancing from the primary causes of our planetary condition [98]. Discourses about environmental crises and damages continue daily, and with this, a sense of despair and powerlessness emerges, a sensation that Glenn A. Albrecht describes as a form of eco-anxiety, *Solastalgia* [99]. Are the social and organizational problems that humans face not better dealt with from a systemic lens? Can efficiencies at the product level help societies in the quest for a more sustainable planet? This tension considers where the primary benefits of the message being delivered are most focused: the planet or the people.

### 3.5.2. Raising Awareness vs. Soliciting Action

The public realm is the space of collective experiences [100]. Increasingly, art and design in the public realm have taken on the goal to enlighten the public about environmental catastrophes [18]. Even if these works aim for social transformation, however, this may require deep shifts in societal structures [101]. Some of these works facilitate emotional experiences [18], while others aim to visualize scientific data and even enable action, through principles of knowledge exchange for environmental issues [102].

Consider Ice-Watch again: The melting blocks of ice are quite clear in their eco-message, and the work's aim to raise awareness is quite evident. The installation is created through science since each of the 12 chunks of ice is equivalent to the global amount of melting ice per second in Greenland. It is difficult to understand how to change the situation of melting glaciers, as the artwork offers no suggestions for how, at the individual level, one can begin to take action. There is no direct solicitation of action, and, given that the problem of melting glaciers requires a systemic understanding of greenhouse gas emissions from a development perspective, viewers are left powerless. Even if the eco-message is extremely clear, the action to be taken to improve the situation is not [4,103].

### 3.5.3. Community vs. Individual

Artworks in the public realm can be aimed at the community or the individual. In some cases, the works may enable dialogues directly in the public realm [104,105]. In these types of works, both communities and individuals, are intended as the audience, which may result in both conceptual or physical processes of interaction [106,107].

The goal in all these types of works in the public realm is to exchange knowledge or disseminate messages [108,109]. Returning once more to Ice-Watch, the work intends to touch an entire community. It sparks an emotional connection between the public (a community of viewers) and the topic of melting glaciers. It may not enable individuals into action, but it makes communities acutely aware of the damages to our environment [110–112]. An example of a work that activates the individual directly is the Washed Ashore eco-art installation by artist, Angela Pozzi. In this work, there is a call for citizens to help collect waste that has washed ashore. This debris, mostly plastic waste, is used by Ms. Pozzi to create the series of artworks exhibited along the shore. Her work enlightens the community at large, but it also focuses on the individual by mobilizing them to take action. This highlights the tension between community or individual-focused design.



**Table 1.** Summary of the tensions defining using data in design sustainability in the public realm.

| Categories                              |   | Tension       | Reference                    |
|---|---|---------------|------------------------------|
| <b>SUSTAINABILITY DOMAIN OF CONCERN</b> | Tension between the social, economic, cultural, and environmental domains of sustainability.  | Environmental | [64–66]                      |
|   |   | Social        | [68,69]                      |
|   |   | Economic      | [68,70]                      |
|   |   | Cultural      | [26,70,71,113]               |
| <b>DATA</b>                             | Tension between collecting data from the community and disseminating data through design to the community.  |               | [27,28,30–36,50,51,72,76,77] |
| <b>DESIGN</b>                           | Tension between designing an entirely new artifact and designing only an add-on.  |               | [78]                         |
|   | Tension between product- and system-based design.   |               | [41,81,83–88,114]            |
| <b>MODE OF DELIVERY OF MESSAGE</b>      | Tension between a physical or virtual type of solution.   |               | [90]                         |
|   | Tension between activating widely accepted knowledge and encouraging provocative debate.  |               | [92–95]                      |
| <b>SUSTAINABLE DEVELOPMENT IMPACT</b>   | Tension between raising awareness and soliciting action.  |               | [4,103]                      |
|   | Tension between community and individual-focused design.  |               | [110–112]                    |
|   | Tension between project benefits to people (and their socioeconomic system) and benefits to the planet (general ecological benefits—flora and fauna, and non-human benefits). |               | [96–99]                      |

#### 4. Methodology

##### 4.1. Approaching City Projects and the Analysis Method

To study how city projects navigate the tension between sustainability, data, design, and eco-messages requires a type of expertise that is rooted in the specific design problems. As proposed by Collins and Evans [1], this would be considered internal expertise. Thus, the researchers analyzing these tensions would also need to understand the outcomes of the design process and designers' intents. The experts who can analyze these projects should have a contributory ability to the topic—e.g., they should be designers focused on studying and creating similar urban projects. As such, the analysis becomes in itself a type of reflection-in-action, as proposed by Schön [115]. This approach is in line with the practices of architectural judgment, such as those used in competitions and design critiques [116,117].

Pedagogical design projects present a fertile space for such analysis to be conducted. Education design projects offer the possibility to formulate briefs and requirements in a way to guide students to explore the tensions presented earlier. Thus, and unlike real-life projects or built case studies, the pedagogical projects' outcomes would all respond to the same requirement and would not be limited by real-life constraints (such as economic or bureaucratic). Additionally, the diversity in student backgrounds and interests would generate a rich variety of projects and ideas to be explored. Moreover, course instructors are fit to provide a polymorphic reflection on design outcomes based on the dialectic instruction and assessment of design-focused projects.

We adopted an expert elicitation process, to involve the teaching team as internal experts who are directly engaged in developing the design projects. Some critiques of this method have been voiced by scholars in public policy development [118,119]. However, this methodology has gained much ground in studying sustainability and sustainable development issues in the last few years. Recently, it has been used to understand and evaluate the SDGs and their links to various sector-driven activities [44,120,121].

##### 4.2. Selected Case Study: Contributing to Sustainability through the Smart City

The case study we selected comprised ten projects, an outcome of a design exercise organized for a first-year public-space sustainable design studio, titled "Contributing

to sustainability through the smart city". This exercise was designed to encapsulate the principles embedded within the theory of eco-didacticism in the public realm. Furthermore, the main objective of this exercise was the democratization of the open data collected and available by the city—data which most often remain hidden from the majority of the urban population. These first-year students were required to imagine how these data can be used in the design of an urban installation, while making the invisibility of the data visible to the public.

In this exercise, the term "smart community" was defined as civil society's contribution to the city's intelligence. This embraces the broader definition of smart cities as suggested by Picon [3]. Students were required to explore how open data can be used in urban design projects such that they can contribute to heightening awareness about sustainability in the community. The design questions that framed the projects were as follows:

1. How can we include civic engagement in the way smart and sustainable communities are developed?
2. What data are needed to enable this civic engagement?
3. If the data do not exist, how would you ensure that information is appropriately and continuously collected?

While the City of Montreal made some data publicly available and accessible to the students, these data were not activated in design by the city. In other words, the data were invisible to the community, even if the datasets were housed on the open data portal in the form of datasets. Some of the datasets were mapped (i.e., using graphical methods to represent specific datasets) on the city's website; however, the city wanted to explore how these data could be utilized more creatively to inform citizens and solicit positive behavior from communities. Some of the design proposals by the city representatives included the following:

- Large-scale public data mapping and visualization;
- Processing and using public data in artifacts that communicate concrete and easy-to-read messages;
- Promoting and valuing contributions from citizens in creating data and information about the city;
- Considering how data are governed when added by citizens to the city's open data portal;
- Helping to recognize the truthfulness and authenticity of a citizen's contribution to data creation;
- Harnessing the potential of digital technology to promote civic engagement and improve democratic practices (e.g., Civic Tech group).

Students could choose from three alternatives regarding how they would incorporate data into their design project:

1. Using existing and already collected data from the city: Students were expected to imagine how these data could be designed into the public realm to help communities better understand their relevance and help them become more aware of sustainability issues. Here, the students focused on disseminating these data through their designs and on "teaching" communities about some sustainability issue, using either dynamic or static interactive methods.
2. Exploring how new data can be collected: The students were expected to find ways to gather new datasets not currently available in the city database. In other words, they designed a mechanism to obtain new data on a regular and sustainable basis.
3. Combining both mentioned strategies: The students were expected to utilize existing data while complementing them with new data or simultaneously collecting and disseminating the data through their design. Thus, their task was to find how the city could collect new data in engaging ways while also seeking new mechanisms and platforms to communicate that same data.

Table 2 presents the ten projects that were used in this study. We have included in this table the title, the submitted poster, and some other details that would enable a comprehensive understanding of each project submitted. In the following section, we describe the analysis process and outcome.

**Table 2.** A summary of the design outcomes, including projects' title, submitted panel, overarching objective, and message of each of the student team projects.



| Project Title and Students' Name   | Illustration  | Problematic              | Overarching Objective                                     | What is the Message or Imperative?   |
|--|---|--------------------------|---|--|
| <p><b>The Power in the Reversibility of Light Pollution</b></p> <p>By: Molly Taylor, Kelly Patilla</p> |   | Light pollution data.    | Introducing a new way of collecting light pollution data. | Taking part in a short activity that will teach people how to measure the brightness of the current sky, which further raises their awareness of the city's light pollution. |
| <p><b>AQI Accessible</b></p> <p>By: Bianca Macleod, John Sales</p>                                     |  | Air quality information. | Monitoring and displaying air quality.                    | Not only educating the public but also providing them a role in gathering data.  |

Table 2. Cont.




| Project Title and Students' Name   | Illustration  | Problematic   | Overarching Objective          | What is the Message or Imperative?   |
|--|---|---|--------------------------------|--|
| <b>Trouble With Takeout</b><br><br><b>By: Jazmin Harrington, Dylan Razzell</b> |  <p>One of the greatest contributing factors to the constantly growing rate of landfills is single use plastics and styrofoam containers.</p> <p>Our project aims to inform consumers on which restaurants and cafes near them have environmentally friendly packaging and which don't.</p> <p>The goal of educating consumers on this subject is that they will consume more environmentally friendly products and motivate shops to sell more eco-friendly products.</p> <p><b>Trouble With Takeout</b> <b>Problème avec emporter</b></p>  <p>We will achieve our goal of educating consumers on this subject by making an installation piece and an interactive application. The installation will be a display of maps and to go interactive with used takeout containers. This will make the viewer aware of the life cycle of these mass consumed products. Adjacent to this installation is an iPad with a survey asking the viewers questions about where they ate in the past day, what kind of container they used and how they disposed of it. This data will be utilized on a mobile application which provides a map stating the different restaurants and cafes in Montreal, and what kind of takeout containers they provide. This will provide incentive for these establishments to provide more eco-friendly takeout containers, thus reducing their impact on the environment.</p> | <p>Growing incidence of single-use plastics and Styrofoam containers.</p> | <p>Developing an app.</p>      | <p>Informing consumers on which restaurants and cafes near them have environmentally friendly packaging.</p>   |
| <b>Car Commute Awareness</b><br><br><b>By: Kevin Mains, Florence Simard</b>    |  <p><b>TRAGIC TRAFFIC CAR COMMUTE AWARENESS</b></p> <p><b>TRAFFIC TRAGIQUE SENSIBILISATION AU TRANSPORT EN VOITURE</b></p>   | <p>An increasing number of cars on roads.</p>                             | <p>Making an installation.</p> | <p>Billboards and lights receive and announce data such as the number of vehicles passing the bridge. The project attempts to decrease air toxicities and traffic.</p> |

Table 2. Cont.

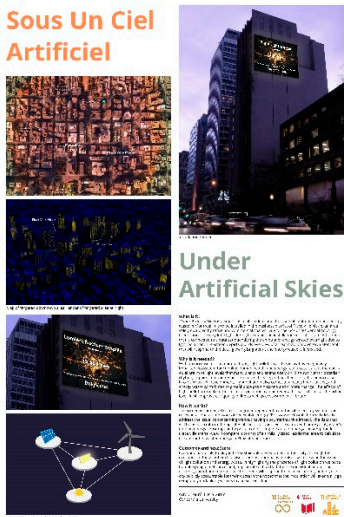
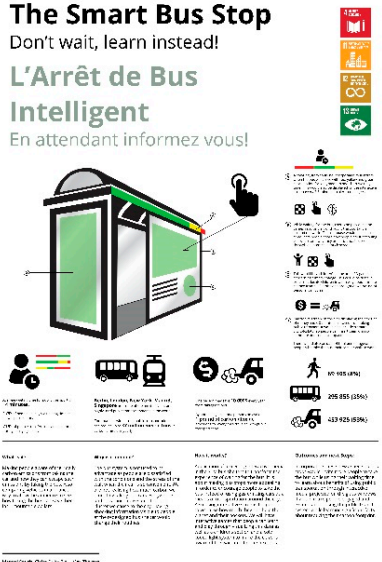
| Project Title and Students' Name  | Illustration   | Problematic                                      | Overarching Objective   | What is the Message or Imperative?   |
|---|--|--|-------------------------|--|
| <p><b>Under Artificial Skies</b></p> <p>By: Astou Touré, Lucia Giron</p>  |  <p><b>Under Artificial Skies</b></p>   | Light pollution and energy waste in Montreal.    | Making an installation. | Quantifying the amount of energy wasted overnight due to light pollution to raise awareness.                                     |
| <p><b>The Smart Bus Stop</b></p> <p>Don't wait, learn instead!</p> <p>By: Manuel Souris, Claire Duby Riou, Max Thomas</p> |  <p><b>L'Arrêt de Bus Intelligent</b></p> <p>En attendant informez vous!</p> | Amount of carbon emissions from individual cars. | Making an installation. | Making people aware of their daily carbon emissions from taking the car and how they can escape such emissions by taking the bus |



Table 2. Cont.



| Project Title and Students' Name   | Illustration   | Problematic   | Overarching Objective   | What is the Message or Imperative?   |
|--|--|---|-------------------------|--|
| <p><b>Our Unsustainable Coffee Habits</b></p> <p><b>By: Laura Porto, Marco Nguyen-Cote</b></p> |  <p><b>OUR UNSUSTAINABLE COFFEE HABITS —</b><br/>Every week, 4 million cups are disposed of in the Greater Montreal region.</p> <p><b>NOS HABITUDES DE CAFÉ INSOUTENABLE —</b><br/>Chaque semaine, 4 millions de tasses de café sont jetées dans la grande région de Montréal.</p>  | Waste generated by the consumption of single-use coffee cups. | Making an installation. | Raising awareness among the residents of Montreal regarding the issue of the waste generated by the consumption of single-use coffee cups. |
| <p><b>Late again?</b></p> <p><b>By: Rees Tucker, Eric Riordon</b></p>                          |  <p><b>LATE AGAIN? ENCORE EN RETARD?</b></p> <p>Even when you plan best to always get there, you can still be late. But what if you could know when you're going to be late before you even leave the house? This is the idea behind the 'Late Again?' app. It's a mobile app that uses real-time data from the Montreal Metro and other transit agencies to predict when you'll be late. It's a free app that's available on both the App Store and Google Play.</p> <p><b>More control over your commute</b><br/>Knowledge is power. Accessible information about transit delay patterns not only improves effectiveness, but also opens up the door to a more broad, systems-oriented way of thinking.</p> | Efficiency in public transportation.                          | Developing an app.      | Increasing efficiency of public transportation in Montreal.  |

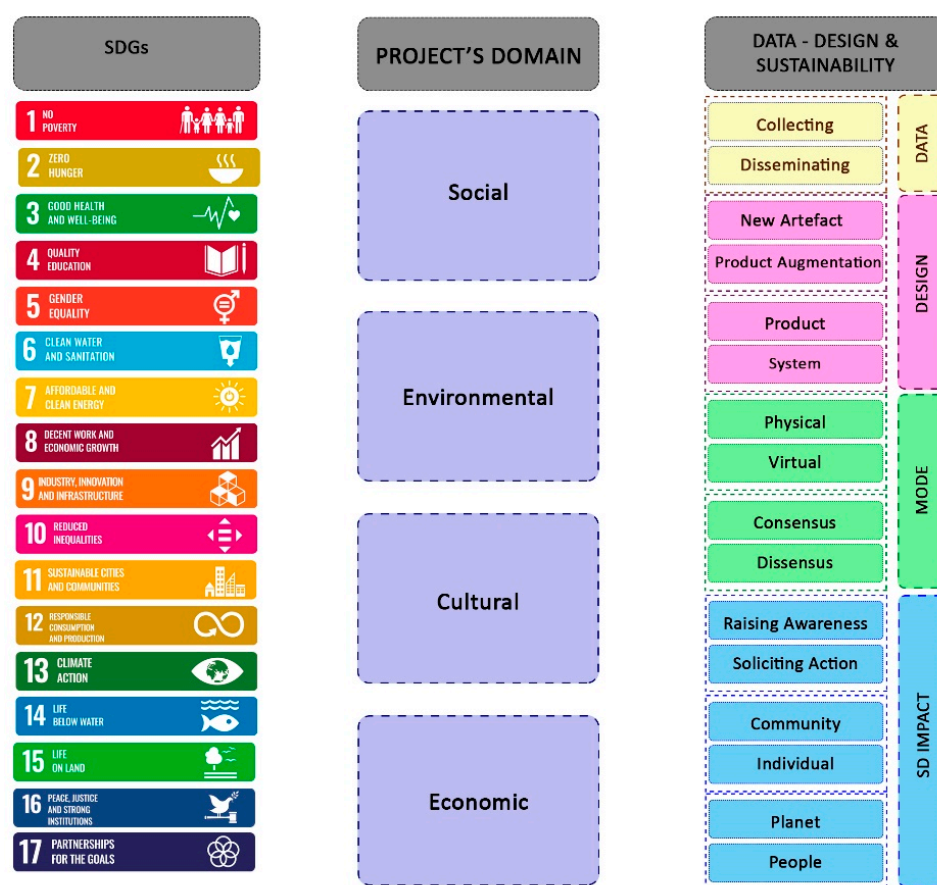
Table 2. Cont.

| Project Title and Students' Name  | Illustration | Problematic  | Overarching Objective | What is the Message or Imperative?   |
|---|--------------|--|-----------------------|--|
| <b>Illuminated Neighborhood</b><br><br><b>By: Anastasia Statsenko, Patrizio McLelland</b> |              | Energy consumption.  | Making installations. | Constructing educational data visualization that urges residents to track their home energy use and to develop more sustainable habits.                    |
| <b>Rootrade</b><br><br><b>By: Lily Cowper, Oldri Kecaj</b>                                |              | Scarcity of Montreal-north grocery stores low-incomes among residents. | Developing an app.    | Acting as a grocery store map and cost-comparison app and allowing busy residents to purchase nutrient-rich vegetables from growers at greenhouses nearby. |

#### 4.3. Analysis Framework

We designed the analysis framework around questions that address the categories presented in Table 1: (1) How does the project relate to the topics of the SDGs? (2) What is the project's sustainability area of concern(s)? (3) How does the project situate within the eight tensions identified—across the data-exchange direction, the design impetus, the mode of message delivery, and the SD impact?

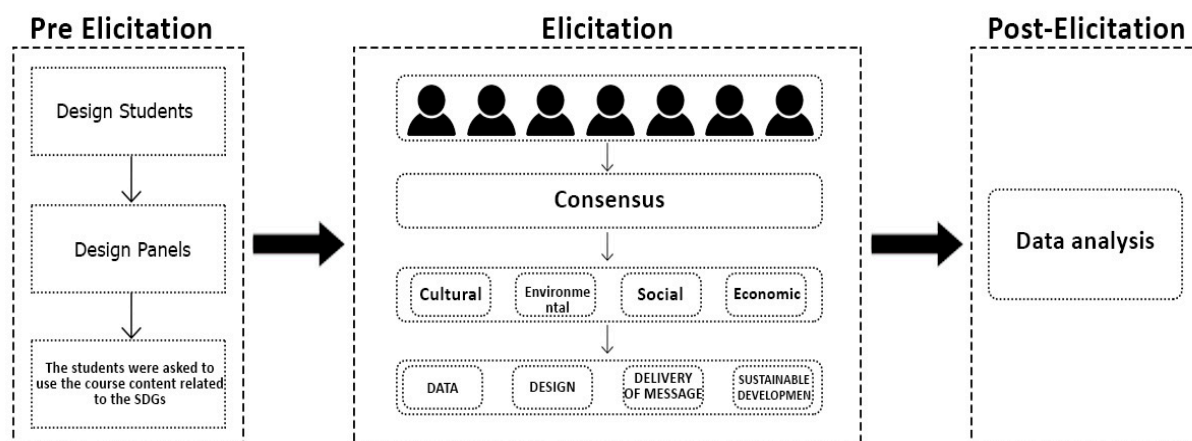
The details of the sub-questions for each of these categories are presented in Appendix A. The overview of the analysis framework is presented in Figure 2.



**Figure 2.** The analytical framework for assessing the design project.

#### 4.4. Analysis Process

To analyze the design outcomes of the young creators, a committee of five experts—including the authors—composed the expert elicitation team. This expert group was composed of the studio instructor, the reviewers, and teaching and research assistants involved in the first-year design studio. The analysis aimed to discuss, judge and critique the projects through the submitted design panels and project descriptions and to arrive at an answer to the questions highlighted in Appendix A. Figure 3 presents the overall process of the structured expert elicitation process.



**Figure 3.** Expert elicitation process. This diagram is based on Reference [119].

As part of their project proposals, the students were asked to select the set of SDGs that they understood could capture their project's objectives. Their choices were based on the course content related to the SDGs (which included a presentation, group discussion, and class activity). Thus, in this research, the students completed the first step in the framework proposed in Figure 2. Following this primary student input, the expert panel completed the remaining analysis, using the structured expert elicitation method proposed in Hemming et al. [119]. The results reported are considered a manifestation of the reviewer's consensus regarding each of the projects, with their justifications presented in the comments. Overall, the 5 experts arrived at a consensus and justified the 120 analysis points. The outcome of this analysis is presented in Appendix B.

## 5. Results

### 5.1. Overview of Results

In terms of the SDGs, the students mostly selected SDG 11 (sustainable cities and communities) as their key area of focus—with all 10 projects linked to it. This was followed by SDG 4 (education), with nine projects. This choice was justified by the will of the students to raise awareness and educate city dwellers about sustainability, ecological, or climate-change-related issues. This is not surprising, since the students were asked to develop a design that would be installed in the public realm and that would allow knowledge exchange or dissemination, using the city's open data or new data collected. Finally, SDG 12 (sustainable consumption and production) also received significant focus, with six projects.

Other SDGs were selected based on the thematic focus of each project, such as food (SDG2), well-being (SDG3), energy (SDG7), infrastructure (SDG9), climate change (SDG 13), biodiversity (SDG 15), and partnership (SDG 17). No projects selected SDG 1 (poverty), SDG 5 (gender equality), SDG 6 (water), SDG 8 (economic growth), SDG 10 (equality), SDG 14 (marine ecosystems), or SDG 16 (peace and strong institutions). While some gaps might be justified by the context of Montreal (such as SDG 6 and 14), other SDGs that were ignored might point to gaps in data's guiding design towards primarily infrastructural and resource-focused sustainability challenges (based on the SDG categories proposed by Lucas et al. [122] and Waage et al. [123]). These findings are shown in Figure 4.

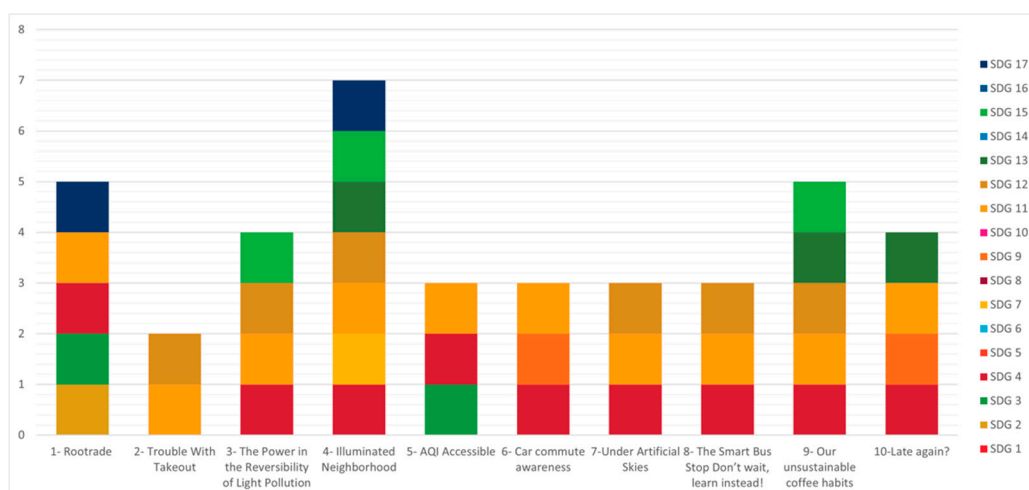
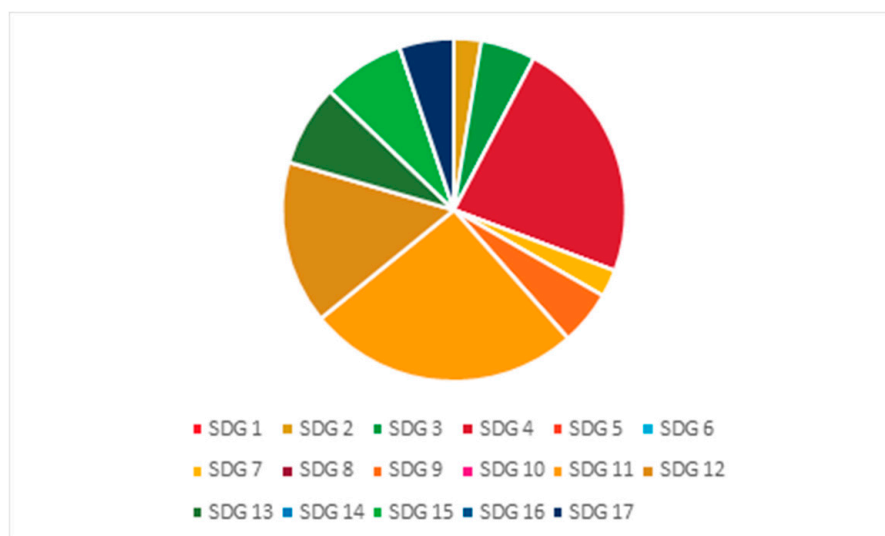


Figure 4. Cont.



**Figure 4.** The Sustainable Development Goals (SDGs) mentioned in students' projects. **(Top)** The SDGs mentioned in each of the students' projects. **(Bottom)** The cumulative SDGs mentioned across all the student projects.

The analysis outcomes showed that most of the students' designs targeted environmental and social sustainability issues, while cultural and economic dimensions were the two least addressed, respectively. Furthermore, the projects all pursued multiple goals, revealing that sustainability work cannot be limited to one specific domain.

Although the focus of most projects was to make environmental improvements, many incorporated different types of interactive processes such that they could perhaps enable changes in cultural or social norms. On the other hand, some projects primarily focused on the cultural or social dimensions, which may have ecological consequences. Figure 5 presents the results of the analysis of the distribution of the four sustainability pillars (environmental, economic, social, and cultural) for each of the design projects (top), as well as the distribution for the combined (of all projects submitted). The units on the top graph of Figure 5 indicate zero bars (not addressed), one bar (minimally addressed), and two bars (highly addressed).

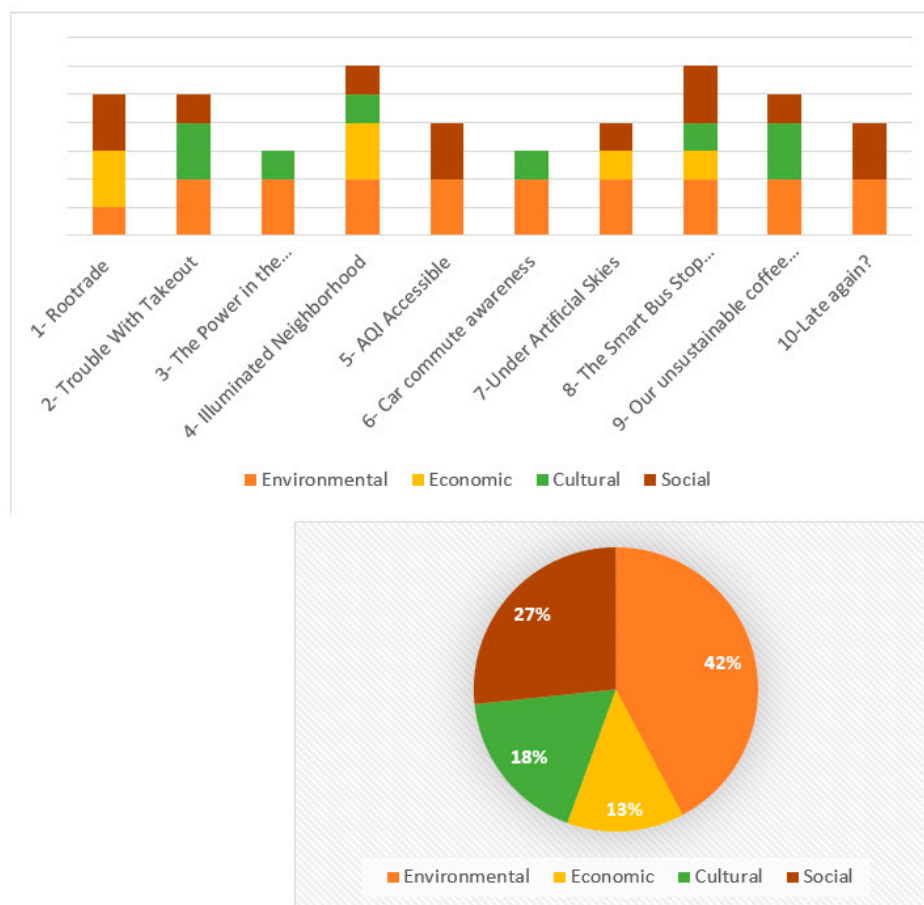
The analysis results for the eight different tensions (within the five categories delineated above) are presented in Figure 6; starting with the tension around data-exchange direction, we see that projects mostly aimed to collect a few pieces of information, while their main intentions were to disseminate the data collected by the city to society. In the design category, the dominant approach in the projects leaned towards designing new artifacts, which may suggest that designing an object from scratch is an easier task than augmenting an available product, which entails analyzing existing flaws and proposing a more suitable alternative.

Looking at the mode of message delivery, there was a higher focus on physical approaches for designs compared to virtual solutions. Although some considered making virtual platforms and networks, the illustrated effects were focused mainly on the changes they could bring about to the physical world. For this reason, most projects are placed in the physical realm. The projects also addressed widely recognized challenges instead of controversial issues that have potential disagreements behind them. This was clear from the selection of the SDGs by the students—mostly avoidant of contested topics such as poverty, gender issues, racial tensions, socioeconomic inequalities, or political challenges.

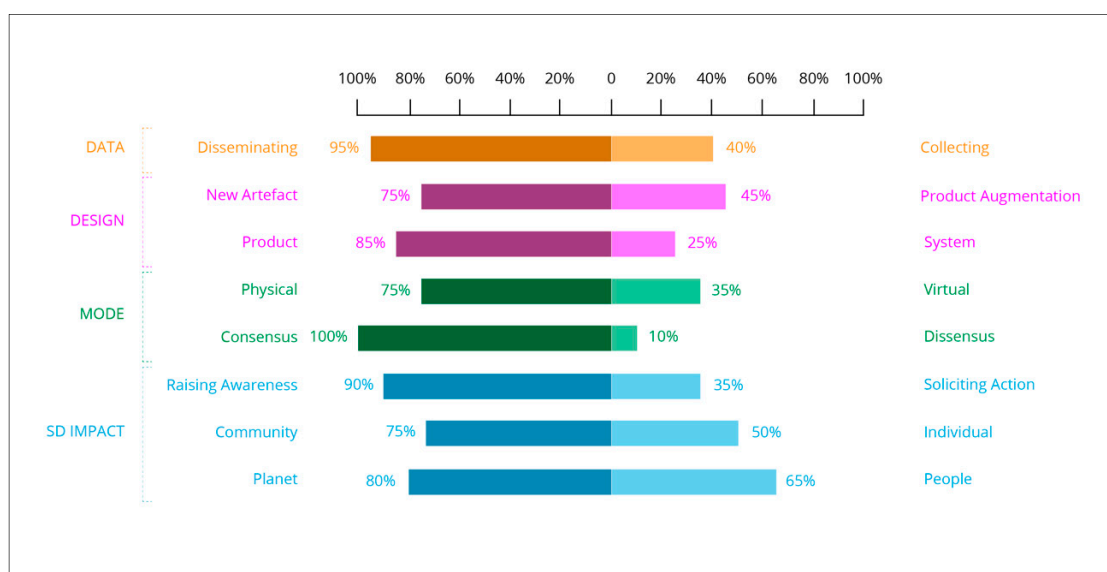
In the sustainable development impact category, the results reveal that most projects tried to raise awareness about sustainability issues rather than solicit positive actions, with a slight bias toward targeting the community rather than the individual, and an overwhelming focus on addressing human-related challenges rather than planetary issues. It was clear that most students struggled in activating data for soliciting actions. This is a



very challenging design approach. We also note that students were unable to conceptually scale the potential for individual actions, resorting to addressing the community as a whole.



**Figure 5.** The results of the analysis of the distribution of the four sustainability pillars (environmental, economic, social, and cultural) for each of the design projects (**Top**), as well as the distribution for the combined (of all projects submitted) (**Bottom**).



**Figure 6.** Cumulative analysis for all projects of the 8 tensions within each of the four categories (data, design, mode, and sustainable development (SD) impact).

Although the designs highlighted the current major sustainability issues and raised awareness around them, they did not demand explicit and immediate actions to solve these problems. The outcomes show that long-term and planet-related goals have received less attention from students (Figure 6).

### 5.2. *Intersecting the Findings and Discussion of Outcomes*

Looking at the assessed parameters and co-occurrences (a Spearman's Correlation was run for all analysis data to determine trends, and we extracted significant correlations starting at 0.05 significance), we see that students generally paired production, distribution, and delivery of goods and services SDGs with natural environmentally focused goals. This further highlights the intent of the projects to improve and provide new products and services in a manner that is more environmentally conscious. We observe that most of the environmentally focused projects are mainly aimed at raising awareness (rather than soliciting action). However, projects that focused on the economic, cultural, or social dimensions presented a broader mix between awareness and action. It is not surprising that the environmental pillar and the mode of consensus for conveying the eco-message were the most heavily adopted strategies across the design projects. These are the low-hanging fruit for design projects that aim to raise awareness.

We also see that projects that aimed at disseminating data depended more on dissensus as a method and tended to have more physical solutions to their design. This might be due to the lack of need for attracting users (through consensus) to collect new data and the fact that the projects aimed to use the public realm (rather than digital devices) to express and illustrate their data. It is far more difficult to propose a design project that adopts a mode of communication-based on dissensus to disseminate a message. This requires a profound understanding of the social issues embedded within the community by the designer in order to address these diverging points of view.

It is clear from the results that most projects that used the physical solutions were less concerned with soliciting actions and more dedicated to raising awareness. On the other hand, virtual solutions were concerned with changing behaviors and attempting to address systemic issues. In most cases where the students sought to collect new data, these data were used to address a social habit that was deemed unsustainable: encouraging turning off office lights after work hours, for example, or finding ways to improve the experience of public transport. These types of unsustainable habits resonated with the young students. However, their proposals remained at the product level and rarely attempted to consider broader systemic viewpoints to capture a deeper level of influence.

These findings suggest the strength and weaknesses of each approach. Physical solutions, in the form of installations and additions to the public realm, emerged in the design process as more suitable for data dissemination and raising awareness about issues around which competing views and values might exist. On the other hand, virtual solutions, in the form of phone apps, were more suitable for data collection and more convenient for soliciting actions guided by a vision for systemic change.

## 6. Discussion and Conclusions

This study focused on the topic of activating data in the public realm for enlightening communities or individuals on issues regarding sustainability. This design practice has been evolving for about two decades, following the realization that corporations are not moving fast enough in their aims to address such issues. Innovative design approaches for reaching the community through small interventions in the city show promise. They offer inventive interactions in the city and facilitate knowledge exchange in unconventional ways. When our 10 project ideas were presented at the final class exhibition, there was much excitement among city representatives. The city's interest in these types of public-space designs indicates, to some degree, that there is a need to suggest varying ways to connect citizens and communities to the difficult topics of unsustainability. Further

exploration of how design practices in the public realm can reach the community, while starting deep dialogues on the diverse topics, comprises a promising future research focus.

However, as crucial as these practices may appear for furthering the targets of sustainability in the city, much research is still needed to better understand the shifts that they engender for individuals, for the community, and corporations as the real culprits of the current environmental predicament. Therefore, another necessary research axis in this field is the study of individual, community, and associated corporate reception of such public-space installations in the short-, medium-, and long-term. This would enable a better understanding of whether changes are taking place, for which stakeholders, and for how long. Such a study would also help improve the public-space installations since it would provide a clearer perspective of the types of installations that are most effective at generating such change.

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## Appendix A. Analysis Questions

Table A1. SDGs.

| SDG  | Which of the SDGs is This Project Aligned with?  |
|--|--|
| Goal 1: No poverty                               | End poverty in all its forms everywhere  |
| Goal 2: Zero hunger                              | End hunger, achieve food security and improved nutrition, and promote sustainable agriculture                          |
| Goal 3: Good health and well-being               | Ensure healthy lives and promote well-being for all at all ages  |
| Goal 4: Quality education                        | Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all                   |
| Goal 5: Gender equality                          | Achieve gender equality and empower all women and girls  |
| Goal 6: Clean water and sanitation               | Ensure availability and sustainable management of water and sanitation for all   |
| Goal 7: Affordable and clean energy              | Ensure access to affordable, reliable, sustainable, and modern energy for all  |
| Goal 8: Decent work and economic growth          | Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all |
| Goal 9: Industry, Innovation, and Infrastructure | Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation             |

**Table A1.** *Cont.*

| SDG   | Which of the SDGs is This Project Aligned with?   |
|---|---|
| Goal 10: Reducing inequalities                  | Reduce income inequality within and among countries   |
| Goal 11: Sustainable cities and communities     | Make cities and human settlements inclusive, safe, resilient, and sustainable   |
| Goal 12: Responsible consumption and production | Ensure sustainable consumption and production patterns  |
| Goal 13: Climate action                         | Take urgent action to combat climate change and its impacts by regulating emissions and promoting developments in renewable energy  |
| Goal 14: Life below water                       | Conserve and sustainably use the oceans, seas, and marine resources for sustainable development   |
| Goal 15: Life on land                           | Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss |
| Goal 16: Peace, justice and strong institutions | Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels           |
| Goal 17: Partnership for the goals              | Strengthen the means of implementation and revitalize the global partnership for sustainable development  |

**Table A2.** Domains.

| What Are the Project's Sustainability Domain(s) of Concern? | 0                                     | 1  | 2                                      |
|---|---------------------------------------|--|--|
| <b>Environmental</b>  | Does not address environmental issues | Somewhat focused on environmental issues | Highly focused on environmental issues |
| <b>Economic</b>   | Does not address economic issues      | Somewhat focused on economic issues      | Highly focused on economic issues      |
| <b>Social</b>   | Does not address social issues        | Somewhat focused on social issues        | Highly focused on social issues        |
| <b>Cultural</b>   | Does not address cultural issues      | Somewhat focused on cultural issues      | Highly focused on cultural issues      |

Table A3. Tensions.

| Tension                     |   | Analysis Question  | Rating   |   |  |
|-----------------------------|---|--|--|---|--|
|                             |   |  | 0  | 1   | 2  |
| DATA-EXCHANGE<br>DIRECTION  | Tension between collecting data from community or disseminating data through design to the community. | Does this project aim at <b>COLLECTING</b> data?                                   | No data are collected.   | The primary function is not about collection.                       | The primary function is data collection.                                   |
|                             |   | Does this project aim at <b>DISSEMINATING</b> data?                                | No data are disseminated.  | The primary function is not about dissemination.                    | The primary function is data dissemination.                                |
| DESIGN<br>IMPETUS           | Tension between designing a new artefact entirely and designing product augmentation.                 | To what extent can this design outcome be considered as a <b>NEW THING</b> ?       | Nothing new.   | Partially new.  | Primarily new.   |
|                             |   | To what extent can design outcomes be considered as <b>ADDs</b> on?                | None of the solutions aim to complement any objects or services. | The design complements by circumstance (not by intention).          | Intended entirely to complement existing services or objects.              |
|                             | Tension between product- and service-based design.  | Does the project aim to design a (short-term) <b>PRODUCT</b> ? Indicate the level. | The design does not address short-term solutions.                | The design proposes short-term solutions for the long-term problem. | The design aims to create a product to propose a short-term solution.      |
|                             |   | Does the project aim to design a (long-term) <b>SYSTEM</b> ? Indicate the level.   | The design does not consider system solutions.                   | The design aims for long-term solutions.                            | The design aims to invent a product to propose a purely systemic solution. |
| MODE OF MESSAGE<br>DELIVERY | Tension between activating widely accepted knowledge vs. encouraging provocative debate.              | What is the level of <b>CONSENSUS</b> this project depends on?                     | The design does not depend on the accepted knowledge.            | The design depends on some accepted knowledge.                      | The design is intended to show accepted knowledge.                         |
|                             |   | What is the level of <b>DISSENSUS</b> this project depends on?                     | The design does not depend on the contested knowledge.           | The design depends on some contested knowledge.                     | The design is intended to show contested knowledge.                        |
|                             | Tensions between a physical or virtual type of solution.  | How much did the design lead to a <b>PHYSICAL</b> solution?                        | No part of the solution is physical.                             | The non-primary part of the solution is physical.                   | The solution is designed to be physical.                                   |
|                             |   | How much did the design lead to a <b>VIRTUAL</b> solution?                         | No part of the solution is virtual.                              | The non-primary part of the solution is virtual.                    | The solution is designed to be virtual                                     |



Table A3. Cont.

| Tension      | Analysis Question   | Rating  |  |  |
|--------------|---|---|--|--|
|              |   | 0   | 1  | 2  |
| SD<br>IMPACT | Tension between raising awareness vs. soliciting action.  | <b>Does this project aim at RAISING AWARENESS?</b>      | The design does not present any new knowledge.           | The design proposes some information, but the primary purpose is not to raise awareness. |
|              |   | <b>Does this project aim at SOLICITING ACTION?</b>      | The design does not present or hint at possible actions. | The design is intended to raise awareness.   |
|              | Tension between community or individual focused design.   | <b>Is this project addressing the COMMUNITY?</b>        | The design does intend to reach the community.           | The design is dependent on people's actions.   |
|              |   | <b>Is this project addressing the INDIVIDUALS?</b>      | The design does intend to reach individuals.             | The design is purely community oriented.   |
|              | Tension between project benefits to people (and their socioeconomic system) vs. planet (general ecological benefits—flora and fauna, and non-human benefits). | <b>Is this project primarily focused on PEOPLE?</b>     | The design does intend to reach individuals.             | The design may impact individual behaviors.  |
|              |   | <b>Is this project primarily focused on the PLANET?</b> | The design does intend to reach individuals.             | The design may impact individual behaviors.  |
|              | Tension between project benefits to people (and their socioeconomic system) vs. planet (general ecological benefits—flora and fauna, and non-human benefits). | <b>Is this project primarily focused on PEOPLE?</b>     | The design is not intended to benefit people.            | The design consequently benefits people.   |
|              |   | <b>Is this project primarily focused on the PLANET?</b> | The design is not intended to benefit the planet.        | The design consequently benefits the planet.   |

## Appendix B. Analysis Outcomes

Table A4. SDGs.

| Projects  | Which of the SDGs is this Project Aligned with? (Based on Student Input)   |
|---|--|
| Roottrade   | Total of five SDGs   |
|   | <ul style="list-style-type: none"> <li>SDG 2</li> <li>SDG 3</li> <li>SDG 4</li> <li>SDG 11</li> <li>SDG 17</li> </ul>      |
| Trouble with Takeout                              | Total of three SDGs <ul style="list-style-type: none"> <li>SDG 11</li> <li>SDG 12</li> <li>SDG 13</li> </ul>               |
| The Power in the Reversibility of Light Pollution | Total of four SDGs <ul style="list-style-type: none"> <li>SDG 4</li> <li>SDG 11</li> <li>SDG 12</li> <li>SDG 15</li> </ul> |

Table A4. Cont.

| Projects                                      | Which of the SDGs is this Project Aligned with? (Based on Student Input) |
|---|--|
| Illuminated Neighborhood                      | Total of seven SDGs  |
|   | • SDG 4  |
|   | • SDG 7  |
|   | • SDG 11   |
|   | • SDG 12   |
|   | • SDG 13   |
|   | • SDG 15   |
| AQI Accessible                                | • SDG 17   |
|   | Total of three SDGs  |
|   | • SDG 3  |
|   | • SDG 4  |
| Car Commute Awareness                         | • SDG 11   |
|   | Total of three SDGs  |
|   | • SDG 4  |
|   | • SDG 11   |
| Under Artificial Skies                        | • SDG 12   |
|   | Total of four SDGs   |
|   | • SDG 4  |
|   | • SDG 11   |
|   | • SDG 12   |
| The Smart Bus Stop Don't wait, learn instead! | • SDG 13   |
|   | Total of three SDGs  |
|   | • SDG 4  |
|   | • SDG 9  |
| Our Unsustainable Coffee Habits               | • SDG 11   |
|   | Total of four SDGs   |
|   | • SDG 4  |
|   | • SDG 11   |
|   | • SDG 12   |
| Late again?                                   | • SDG 15   |
|   | Total of three SDGs  |
|   | • SDG 4  |
|   | • SDG 9  |
|   | • SDG 11   |

Table A5. Domains.

| Projects   | Environmental | Economic | Cultural | Social | Justification   |
|--|---------------|----------|----------|--------|---|
| <b>Roottrade</b>   | 1             | 2        | 0        | 2      | It services an underprivileged group of citizens. The project is to support economic activities that will have a positive social impact (for people with low access to fresh food).   |
| <b>Trouble with Takeout</b>                              | 2             | 0        | 2        | 1      | The aim is to create environmental improvements (lowering the use of single use packaging) through a change in the consumption culture (adding packaging characteristics as a layer in the decision to consume food).   |
| <b>The Power in the Reversibility of Light Pollution</b> | 2             | 0        | 1        | 0      | The project is mainly focused on the dangers of light pollution (as an ecological and environmental problem).   |
| <b>Illuminated Neighborhood</b>                          | 2             | 2        | 1        | 1      | The idea is to reduce energy consumption (an environmental problem), which is closely related to the economic domain (infrastructure and cost). However, the design aims to change the focus on energy consumption from the individual to a communicably/cultural domain. |
| <b>AQI Accessible</b>                                    | 2             | 0        | 0        | 2      | Air quality is a human health issue that has gained a lot of interest lately. It also has an environmental/ecological significance (in this case, only referred to indirectly).   |
| <b>Car Commute Awareness</b>                             | 2             | 0        | 1        | 0      | Awareness about the environmental effects of a cultural problem (car use).  |
| <b>Under Artificial Skies</b>                            | 2             | 1        | 0        | 1      | The design aims to connect the environmental economic and social dimensions of the problem of energy waste.   |
| <b>The Smart Bus Stop Don't wait, learn instead!</b>     | 2             | 1        | 1        | 2      | The project aims to connect—in a weak way—to all the domains: co2 reduction, money savings, shift from car culture, and improvement in the quality of life.   |
| <b>Our Unsustainable Coffee Habits</b>                   | 2             | 0        | 2        | 1      | Presenting a cultural problem with environmental consequences.  |
| <b>Late Again?</b>                                       | 2             | 0        | 0        | 2      | Solving a social problem.   |

Table A6. Data-exchange direction and design impetus.

| Projects  |               | DATA-EXCHANGE DIRECTION   | DESIGN IMPETUS   |  |
|---|---------------|---|--|--|
|   |               | COLLECTING/DISSEMINATING  | NEW ARTEFACT/PRODUCT AUGMENTATION  | PRODUCT/SYSTEM   |
| Roottrade   | Justification | It is an application that provides key information to citizens. Some data regarding groceries and greenhouses will be collected to be disseminated to the wider community (collecting information from a few to disseminate to the many). | The solution sits in between both scales. The network/platform is new, but it is not a new device. It attaches to the existing infrastructure but does not augment its functions (only its reach). | This is a quick solution to alleviate the food desert problem in some communities. The project mainly aims to create a short-term solution for food access (does not aim to change the system that resulted in food-insecurity). However, such a platform could enable systemic change for access to locally grown fresh foods.  |
|   | Rating        | Collecting: 1<br>Disseminating: 2   | New Artefact: 1<br>Product<br>Augmentation: 0  | Product: 2<br>System: 1  |
| Trouble with Takeout                              | Justification | Collecting information from a few (restaurants/cafes) to disseminate to the many (wider society).   | The platform is new. However, the design completely attaches to existing artefacts (available packaging solutions).  | The design tackles a currently existing tension (sustainable vs. unsustainable packaging solutions). What will happen if all the packages are sustainable? (left un-answered). It also does not provide an alternative to single use packaging, but rather depends on small incremental improvements (less harm approach).   |
|   | Rating        | Collecting: 1<br>Disseminating: 2   | New Artefact: 2<br>Product<br>Augmentation: 1  | Product: 2<br>System: 0  |
| The Power in the Reversibility of Light Pollution | Justification | The design mainly aims at collecting data (large datasets) to make available to regulators and policy makers (a small group of people with decision-making power).  | The design entails creating a new system/device to collect data, but it depends on the existing lighting artefacts and conditions.   | It aims to create a product to collect data (short-term solution for a current problem). However, the suggested lighting control and optimization could change the underlying definition of the current system (night pedestrian and artificial lighting of the city) from always-on to on-demand. This does not question the need for lighting or propose changes to infrastructures. |
|   | Rating        | Collecting: 2<br>Disseminating: 1   | New Artefact: 2<br>Product<br>Augmentation: 0  | Product: 1<br>System: 1  |

Table A6. Cont.

| Projects  |               | DATA-EXCHANGE<br>DIRECTION   | DESIGN IMPETUS   |  |
|---|---------------|--|--|--|
|   |               | COLLECTING/<br>DISSEMINATING   | NEW ARTEFACT/<br>PRODUCT<br>AUGMENTATION   | PRODUCT/SYSTEM   |
| Illuminated<br>Neighborhood                         | Justification | Project aims to create devices to communicate and visualize energy data.                 | The devices are new. However, they attach to the existing grid. There is no solution proposed to encourage alternative grids or other energy systems.      | No system change solutions are proposed, only a device to help people visualize the outcome of their decisions in the current energy system.   |
|   | Rating        | Collecting: 0<br>Disseminating: 2  | New Artefact: 2<br>Product<br>Augmentation: 1  | Product: 2<br>System: 0  |
| AQI Accessible                                      | Justification | Collecting some information (a few air-quality stations) to be disseminated to the many. | The design proposes to use existing stations and increase the infrastructure for air quality measurement. It proposes a new device for communicating data. | No solution or alternatives are proposed.  |
|   | Rating        | Collecting: 1<br>Disseminating: 2  | New Artefact: 2<br>Product<br>Augmentation: 1  | Product: 2<br>System: 0  |
| Car Commute<br>Awareness                            | Justification | Equally focused on both.   | A new system to communicate data that is attached on a bridge (but could be attached to any other infrastructure).   | A device for communicating data. Does not attempt to improve or propose new product or alternatives.   |
|   | Rating        | Collecting: 1<br>Disseminating: 2  | New Artefact: 2<br>Product<br>Augmentation: 1  | Product: 2<br>System: 0  |
| Under Artificial Skies                              | Justification | Some new data to be collected but mainly a dissemination device.                         | The project is based on data from the current system. A new energy grid is proposed to power the installation itself.                                      | It is a weird approach to propose fighting light pollution by using an LED screen. The design is focused on making the problem visible, but not on guiding people toward a solution. |
|   | Rating        | Collecting: 1<br>Disseminating: 2  | New Artefact: 1<br>Product<br>Augmentation: 1  | Product: 2<br>System: 0  |
| The Smart Bus<br>Stop Don't wait,<br>learn instead! | Justification |  | Attaching to bus stops. A new device for disseminating info.   | No long-term solutions proposed.   |
|   | Rating        | Collecting: 0<br>Disseminating: 2  | New Artefact: 1<br>Product<br>Augmentation: 2  | Product: 2<br>System: 0  |



Table A6. Cont.

| Projects                           |               | DATA-EXCHANGE<br>DIRECTION                         | DESIGN IMPETUS  |   |
|------------------------------------|---------------|--|---|---|
|                                    |               | COLLECTING/<br>DISSEMINATING                       | NEW ARTEFACT/<br>PRODUCT<br>AUGMENTATION  | PRODUCT/SYSTEM  |
| Our Unsustainable<br>Coffee Habits | Justification |  | Based on existing data and artefacts and creating an installation (not a device). | A short-term awareness raising approach—no alternatives.  |
|                                    | Rating        | Collecting: 0<br>Disseminating: 2                  | New Artefact: 1<br>Product<br>Augmentation: 0                                     | Product: 2<br>System: 0   |
| Late Again?                        | Justification | Some new data, but mainly disseminating/analyzing. | It is an add on for transit app.  | No system change ideas are proposed. Proposes an incremental change to the current public transit system. |
|                                    | Rating        | Collecting: 1<br>Disseminating: 2                  | New Artefact: 1<br>Product<br>Augmentation: 2                                     | Product: 1<br>System: 2   |

Table A7. Mode of message delivery.

| Projects  |               | MODE OF MESSAGE DELIVERY   |  |
|---|---------------|--|--|
|   |               | VIRTUAL/PHYSICAL   | CONSENSUS/DISSENSUS  |
| Roottrade   | Justification | It provides facts. The idea of connecting people to local/sustainable food sources is widely accepted. Yet, the price comparisons could result in discussion and disagreements on the value of local foods (in comparison to large retailers). | The application points to greenhouses and grocery stores, but does not create new spaces, just points to ones that exist. The solution has a relation to physical food growing and retail services. It also serves to create a virtual community for the users (a network/platform).       |
|   | Rating        | Consensus: 2<br>Dissensus: 0   | Virtual: 2<br>Physical: 1  |
| Trouble with Takeout                              | Justification | There is a consensus on the need to shift from single use packages. This works to place pressure on retailers to make the shift (possible loss of income/profit).  | The design aims to create a virtual space of knowledge about packaging. That is only connected to one aspect of the physical world (the packaging). It does not consider other aspects. The effect could lead to change in the physical world as well (i.e., reduction in landfill waste). |
|   | Rating        | Consensus: 2<br>Dissensus: 0   | Virtual: 2<br>Physical: 0  |
| The Power in the Reversibility of Light Pollution | Justification |  | The design aims to collect physical (light) data and results in physical solution (changing the light distribution and intensity plans of the city)  |
|   | Rating        | Consensus: 2<br>Dissensus: 1   | Virtual: 1<br>Physical: 2  |

Table A7. Cont.

| Projects                                      |               | MODE OF MESSAGE DELIVERY  |  |
|---|---------------|---|--|
|   |               | VIRTUAL/PHYSICAL  | CONSENSUS/DISSENSUS  |
| Illuminated Neighborhood                      | Justification | The design creates a physical object.   |  |
|   | Rating        | Consensus: 2<br>Dissensus: 0  | Virtual: 0<br>Physical: 2  |
| AQI Accessible                                | Justification | A consensus (fact) of air quality status. However, a dissensus on the use of knowing such info.   | A physical station with a physical screen.                                       |
|   | Rating        | Consensus: 2<br>Dissensus: 0  | Virtual: 0<br>Physical: 2  |
| Car commute awareness                         | Justification | Consensus on the negative impact of car use. Could lead to dissensus on actions needed within the community.  |  |
|   | Rating        | Consensus: 2<br>Dissensus: 0  | Virtual: 0<br>Physical: 2  |
| Under Artificial Skies                        | Justification | Reduction of energy waste is widely accepted. How it could be achieved is a key point of tension.   | Energy waste is a virtual problem. That is here translated to a physical object. |
|   | Rating        | Consensus: 2<br>Dissensus: 0  | Virtual: 0<br>Physical: 2  |
| The Smart Bus Stop Don't wait, learn instead! | Justification | Negative effect of car use is widely accepted. The effectiveness of public transit as an alternative (in its current conditions in Montréal/Canada) could be a topic of disagreement. |  |
|   | Rating        | Consensus: 2<br>Dissensus: 1  | Virtual: 0<br>Physical: 2  |
| Our Unsustainable Coffee Habits               | Justification |   |  |
|   | Rating        | Consensus: 2<br>Dissensus: 0  | Virtual: 2<br>Physical: 0  |
| Late Again?                                   | Justification | Virtual knowledge is being created.   |  |
|   | Rating        | Consensus: 2<br>Dissensus: 0  | Virtual: 2<br>Physical: 0  |

Table A8. SD impact.

| Projects  | SD IMPACT                           |   |  |
|---|-------------------------------------|---|--|
|   | RAISING AWARENESS/SOLICITING ACTION | COMMUNITY/INDIVIDUAL  | PEOPLE/PLANET  |
| Roottrade   | Justification                       | It is both a community solution and one that touches individuals directly. The solution is focused on providing individuals with knowledge for food access. On the broader scale, by encouraging purchases from local growers, it could have community level impacts. | While there might be secondarily environmental benefits, they are not articulated in the intent of the project.                                      |
|   | Rating                              | Raising Awareness: 1<br>Soliciting Action: 1  | Community: 2<br>Individual: 2<br>People: 2<br>Planet: 1  |
| Trouble with Takeout                              | Justification                       | The solution is focused on providing individuals with knowledge on packaging and to encourage individual retailers to change their packaging. On the broader scale, by encouraging this shift to sustainable packaging, it could have community level impacts.        | The change from single use has some human benefits but it mainly aims at lowering the ecological footprint of to-go foods.                           |
|   | Rating                              | Raising Awareness: 2<br>Soliciting Action: 2  | Community: 1<br>Individual: 2<br>People: 1<br>Planet: 2  |
| The Power in the Reversibility of Light Pollution | Justification                       | The awareness portion of the project aims to target building knowledge in the community. The possible outcomes will also be felt on the community level (changes in citywide lighting patterns—rather than individual use of lights for example).                     | The problem is mainly ecological (although not articulated as such). There might be benefits to humans (health wise) but they are only secondary.    |
|   | Rating                              | Raising Awareness: 2<br>Soliciting Action: 0  | Community: 2<br>Individual: 0<br>People: 1<br>Planet: 2  |
| Illuminated Neighborhood                          | Justification                       | The focus is on creating community experiences of lighting informed by energy use. However, this energy use is individual (people individually will have to change their energy use to create changes in the consumption).  | The energy reduction helps people economically. Could have environmental benefits, but they are not intended nor articulated.                        |
|   | Rating                              | Raising Awareness: 2<br>Soliciting Action: 1  | Community: 2<br>Individual: 1<br>People: 1<br>Planet: 2  |
| AQI Accessible                                    | Justification                       | Air quality is a community issue. The power of the individual in creating change is limited.  | Human health and quality of life is the main intent indicated. There could be some planet/ecological benefits, but the design does not address them. |
|   | Rating                              | Raising Awareness: 2<br>Soliciting Action: 0  | Community: 2<br>Individual: 0<br>People: 2<br>Planet: 1  |

Table A8. Cont.

| Projects                                      |               | SD IMPACT   |  |  |
|---|---------------|---|--|--|
|   |               | RAISING AWARENESS/SOLICITING ACTION   | COMMUNITY/INDIVIDUAL   | PEOPLE/PLANET  |
| Car commute awareness                         | Justification | Unclear what action is required. It mainly aims to raise awareness                          | A sort of public shaming. The Co2 measurement aims to shift the individual use pattern to a community level problem. | Open to interpretation on both ends, but weak in both cases.                         |
|   | Rating        | Raising Awareness: 2<br>Soliciting Action: 0  | Community: 1<br>Individual: 1  | People: 1<br>Planet: 1   |
| Under Artificial Skies                        | Justification | No clear understanding of how individuals can take action.                                  | It is unclear how individuals could act. the Intent is to hold the community accountable.                            | The intent describes some planetary benefits, but the main focus is anthropocentric. |
|   | Rating        | Raising Awareness: 2<br>Soliciting Action: 0  | Community: 2<br>Individual: 0  | People: 1<br>Planet: 2   |
| The Smart Bus Stop Don't wait, learn instead! | Justification | Increase the use of public transit, but mainly raise awareness on the negatives of car use. | A small community target (change of car culture), but people are primarily individually targeted.                    | mainly focused on people their health and well-being.                                |
|   | Rating        | Raising Awareness: 2<br>Soliciting Action: 1  | Communit: 1<br>Individual: 1   | People: 1<br>Planet: 2   |
| Our unsustainable coffee habits               | Justification | Action is secondary in this design.   | A community problem, but also targeting individual choices.  | It is ambiguous; all the benefits are secondary.                                     |
|   | Rating        | Raising Awareness: 2<br>Soliciting Action: 0  | Community: 1<br>Individual: 1  | People: 1<br>Planet: 2   |
| Late again?                                   | Justification | Awareness about bus efficiency, a social problem  | Improving commute for individuals, but mainly leading to more community trust in public transit info.                |  |
|   | Rating        | Raising Awareness: 1<br>Soliciting Action: 2  | Community: 1<br>Individual: 2  | People: 2<br>Planet: 1   |

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