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Activating key principles of systemic design through exploratory prototyping

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Abstract: Working towards sustainable futures demands competencies and methodologies that support system thinking and action. While prototyping has been designated as a promising method to facilitate complex systemic design processes, studies proving this potential are scarce, and scholars call for a shift in the definition and use of traditional prototyping when applied in design processes targeting complex systems. This paper describes the observed contributions of exploratory prototyping in the emergence of systemic design principles. Results from three systemic design workshops illustrate the role that exploratory prototyping played in the understanding and framing stages of design processes targeting complex systems, particularly in the appreciation of the systems' complexity, the recognition of interdependence relationships among its elements, and the framing of the system's boundaries to set the systems' new vision. Our findings contribute to envisioning new definitions and uses of prototyping to respond to the demands of the systemic design practice.

Keywords: exploratory prototyping; systemic design; systemic design principles;

1. Introduction

Current societal and natural issues encompass large, socio-technical systems and demand innovative design approaches to engage in the challenges they present (Irwin 2011, Norman & Stappers 2016). Accordingly, emergent and traditional design practices are cross-pollinating, enabling connections, collaborations and learnings to transform existing systems into desirable futures. Yet, researchers and practitioners request new ways and frameworks to deal with complex systems (Norman and Stappers 2016, Mulder and Loorbach 2018).

This paper first explores the principles of systemic design. Our goal is to understand the premises of the discipline that should be stimulated through tools and methods. Then, we argue the role of exploratory prototyping in activating the identified principles and review how this method can be a valuable asset for researchers and practitioners.



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At the intersection between systems thinking and design, systemic design includes a range of practices that look into generating change in complex issues using design. Systemic design emerges as a promising practice to address sustainable futures (Jones 2014, Jones & Sevaldson 2019, Buchanan 2019, Ryan 2014). In Jones' (2017) words, the "ultimate aim of systemic design is to co-design better policies, programs and service systems with the participants in those systems." This emerging design practice integrates systems thinking and methods for designing complex, multi-system and multi-stakeholder services and programs across society (Jones 2017). Yet, the tools and methods of this practice remain underdeveloped.

Prototyping has remarkably supported collaborative design processes and is recognized as a promising method to facilitate systemic design processes. However, little research has been done to prove this potential (Maiorana 2021). Some scholars inquire a shift in the definition and use of traditional prototyping and representation methods when applied in design processes targeting complex systems (Blomkvist 2014, Maiorana 2021, Schulman 2010, Ricigliano 2015). Particularly, researchers like Kimbell and Bailey (2017) feature the application of prototyping with an exploratory logic to target complex systems, such as policy-making. Exploratory prototyping is understood as "inventive moments of synthesis" (Wilkie and Farias 2015) that (re)assemble current and future actors, artefacts, practices, identities and outcomes (Kimbell and Bailey 2017). These authors emphasise the value of prototyping as a method for exploration due to its capability to enable learning, mediation between actualities and potentialities, and provisionality when exploring ideas. Based on this idea, we hypothesise that exploratory participatory prototyping has the potential to support systemic design processes and contribute to the future of this practice. To do so, the paper elaborates on systemic design theory. In particular, we set our attention to three papers that present the principles that define the work of systemic design practitioners as a reference to understand the discipline.

Using the experience of three systemic design workshops targeting sustainable urban transformations, we study the role of exploratory prototyping in activating systemic design principles. The results show how exploratory prototyping became a significant asset for participants. Representing the system through tangible materials facilitated cognitive and creative processes around the system. Participants recognised the added value of exploratory prototyping in understanding the system's complexity, envisioning a new purpose, and identifying meaningful opportunities.

2. Literature review

2.1 Systemic design principles

Principles are inherent to systemic design. Design principles provide a foundation for practitioners to engage in their practices (Jones 2014). Given the complexity of systemic design, its principles acquire a greater centrality. In complex systems design, the routinary sequencing of a linear design process is unattainable, so principles function as a compass to orient prac-

titioners in various situations. The definition of systemic design through their principles resonates with Jones’ (2014) description of systemic design “not as a design discipline but an orientation”.

In this section, we provide an overview of existing characterisations of the systemic design practice as a reference point to understand the principles guiding this practice. To do so, we selected two academic papers that specifically verse on systemic design principles (Jones 2014 and Bijl-Brouwer and Malcolm 2020). Remarkably cited in the systemic design literature, they are the only two papers that study and propose design principles for complex systems. Additionally, we include the report on System-Shifting Design by The Design Council. In the report, system-shifting design – included in the systemic design practice (Bijl-Brouer 2023) – is described “from the observations of designers across the world who are working to deliberately and generatively create new systems of planetary health and wellbeing” (Drew et al., 2022). This non-academic publication was included for two reasons: 1) for the depiction of the systemic design practice from the perspective of design teams, showing examples from specific projects contrasted with academic publications and other similar reports, and 2) for the extended recognition and credibility of the Design Council in studying and supporting the design community towards a more just and sustainable world. Nevertheless, it is important to mention that Drew et al. (2021) differentiate between “characteristics” (what is designed) and “principles” (how is designed) to describe system-shifting design and that both categories were considered for the study of principles of this paper.

Table 1 presents a list of principles extracted from the three publications. While some of the principles mentioned in the three sources correlate, others are exclusively disclosed in one publication. Only principles mentioned in at least two of the three sources were considered for this study. In the first column of the table the principles were unified under a concurrent name. Each principle is further explained in this section, and used as a reference for the analysis of the results of the workshops in section 4 (Findings).

Table 1 Systemic design principles.

Combined principle	How is design evolving to create the systems we need? (Drew et al. 2021)	Systemic design principles in social innovation (van der Bijl-Brouwer and Malcolm 2020)	Systemic Design Principles for Complex Social Systems (Jones 2014)
Acknowledging and appreciating the system's complexity	+ work at 3 levels of the system (micro, macro, meso) + seeing things (designs) as part of a bigger thing	+ developing empathy with the system	+ appreciating complexity systems ordering
Recognizing interrelat-	+ perception of interdependence	+ interrelatedness	(not expressly mentioned)

edness/in- terdepend- ence			
Framing or reframing the sys- tem's boundary	<i>(not expressly men- tioned)</i>	+ open up problem space	+ boundary framing or reframing
Establishing a vision for the system	+ challenge the deep structure of a system + Working to an alterna- tive intention + supporting the transi- tion to a new model	+ evolutionary ap- proach	+ identifying an ideal state + purpose finding + continuous adaptation
Concentrat- ing on rela- tions(hips)	+ reconfiguring relations that unlock or invite new behaviors	+ focus on relation- ships instead of end- users	<i>(not expressly men- tioned)</i>
Promoting multifac- eted strate- gies to ena- ble change	+ supporting others to embody/experience/im- agine alternatives	+ influencing mental models to enable change	+ self-organization

Acknowledging and appreciating the systems' complexity

All three references emphasise the understanding of the system and its complexity as a crucial point of departure for systemic design. What Van der Bilj-Brouer and Malcolm (2020) call "developing empathy with the system" entails the exploration of the problem space, noticing the numerous factors and relationships demonstrating the complexity of the system. This initial problem identification is essential for establishing a frame of reference to act upon (Jones 2014). The Design Council (Drew et al. 2021), when studying the work of systemic design practitioners, distinguish their work in three levels: (1) with services and business models at the micro level, (2) by shaping narratives, paradigms, and values that contribute to broad changes occurring at the macro level, and (3) by working with policymakers and regulators to generate new relationships, markets, educations, platforms and infrastructure supporting new frameworks for the systems (meso level). Accordingly, being familiar with the system at all three levels is fundamental for designers to connect the elements of the system in innovative ways and generate solutions that operate together in the bigger system.

Recognizing interrelatedness

An essential aspect of working within systems is the perception of interdependence among the elements of the system. This interconnectivity and interdependency forge the practice of systemic design. By recognising the complex nature of the system, practitioners realise that the problems they are addressing cannot be solved independently (van der Bijl-Brouwer and Malcolm 2020); they require a systemic design approach to tackle the problem.

Framing or reframing the systems' boundaries

According to van der Bijl-Brouwer (2023), systemic design differs from systems design in the system's boundary. While systems design targets systems whose boundaries can be objectively defined (e.g. technical systems designed by systems engineers), systemic design addresses systems whose boundaries cannot be objectively defined (e.g. healthcare systems or educational systems). Consequently, systemic design practice requires a conscious and iterative process of selecting boundaries and reflecting on the associated meanings of such boundary framing (Jones, 2014). For framing, practitioners consider various conceptual design options before concluding on a purpose (ibid).

Establishing a vision for the system

The determination of a new vision or purpose for the system to work or design towards is one of the pillars of the systemic design practice. That ideal state or envisioned future scenario, determined by agreement, serves as a reference point to orient practitioners' actions (Jones 2014).

In most cases inspired by the malfunctioning of the existing system, practitioners visualise an alternative set of characteristics of the system they want to move towards (Drew et al. 2021). In the words of Leadbeater and Winhall (2020), this new vision is "not just a different goal to be reached but a different philosophy to be enacted". They adopt an Evolutionary Design Approach to allow or facilitate that new system to unfold (van der Bijl-Brouwer and Malcolm 2020), taking multiple design steps to shift the system in the desired direction. Those steps include, on the one hand, developing a portfolio of new products, services, spaces, or models that, acting "like a fractal" (Drew et al. 2021), generate small shifts at different scales that trigger a big change in the wider system. On the other hand, systemic designers also invest in activities that support the system's transition (Drew et al. 2021); that is, activities that generate certain conditions that enable new system activity to emerge, settle and grow, such as infrastructuring (Hillgren et al. 2011, Manzini 2015), activating stakeholders, building platforms for action, establishing or strengthening the relationships among actors.

Concentrating on relationships

Systems are defined as collections of things arranged and related to form a unity (Buchanan 2019), indicating a fundamental relational sense among parts. Consequently,

systemic design focuses on relationships instead of end-users (Van der Bijl-Brouwer and Malcolm 2020). Moving beyond human-centeredness' attention to the particular needs and aspirations of individuals, practitioners of systemic design concentrate on relationships, particularly in the diversity of perspectives among stakeholders.

The focus on relationships also shapes systemic design interventions. Practitioners target system change by reconfiguring, promoting, strengthening, fostering or supporting these relationships to unlock or invite new behaviours (Drew et al. 2021). In other words, systemic design solutions facilitate the reconfiguration of actors in ways that enable the system to generate the envisioned new value system (Leadbeater and Winhall 2020).

Promoting multifaceted strategies to enable change

The consulted studies on systemic design agree on activating a portfolio of design strategies and interventions at different system levels to generate the envisioned change. Jones (2014) emphasises the limited capacity of the individual designer as an agent of change. Yet, he acknowledges designers' potential to facilitate cooperative organisation among actors, placing co-design, high-quality dialogue and facilitation skills at the forefront of this practice, coinciding with van der Bijl-Brouwer and Malcolm (2020). Drew et al. (2021) insist on the ripple effect of facilitating shifts in different areas of the system to achieve significant change in the wider ecosystem. Van der Bijl-Brouwer and Malcolm (2020) also feature the influence on mental models (described as "socially learned ways of perceiving and organising information") through tangible interventions to enable change. With this purpose, Drew et al. (2021) suggest using imagination as an "infrastructure for the alternative", valuing the revelation of potential alternatives that can be embodied or experienced.

2.2 The potential of exploratory prototyping in systemic design

Systemic design's ambitious goals require tools that move beyond the traditional tools in the design practice (Jones 2017). Van der Bijl-Brouwer (2023) criticises the inadequacy of conventional design processes and methods for addressing complex systems. Similarly, Drew et al. (2021), in their report on systems-shifting design, call for the collective reconceptualisation of the languages and tools that operate in the current design system. As the discipline is only emerging, they wonder: "What are the new tools, materials and language of system shifting design? What do we need for revealing and making?" (Drew et al. 2021, 68).

A number of practitioners and researchers acknowledge prototyping for its potential to contribute to tackling complex social issues (Maiorana 2021, Kimbell and Bailey 2017, Chow 2013, Hillgren et al. 2011). However, there are not many studies on the specific contributions of prototyping to systemic design processes (Maiorana 2021). In the same way that conventional design methods are insufficient to meet the needs of systemic design, prototyping needs to be re-examined according to the needs of this emergent design practice. In

that regard, Drew et al. (2021) state that prototyping, used to validate assumptions, may be "unhelpful" when creating next-generation systems.

Kimbell and Bailey (2017) propose an alternative prototyping logic when applied to complex systems such as those targeted in policy-making: instead of being a "proof of concept", prototypes are applied from the early stages of the design process following an exploratory logic to challenge the *status quo*.

Exploratory prototyping is nothing new. Floyd (1984) already described exploratory prototyping as one of the three approaches of prototyping. In her text, a collection of reflections from the discussions among committee members for the preparation of the Working Conference in Prototyping, she describes exploratory prototyping as a "catalyst to elicit good ideas and to promote a creative cooperation between all parties involved" (Floyd 1984, p.6). She distinguishes this type of prototyping from the traditional experimental prototyping approach by their intended goals; exploratory prototypes are not focused on validating one particular solution but to facilitate the proposal and discussion of alternative solutions.

In the last decades, new forms of prototypes following the exploratory logic – such as empathy probes (Mattelmäki & Battarbee, 2002) or sensitizing tools (Visser et al., 2005) – emerged to facilitate new needs in the design space (Sanders 2013). This approach to prototyping is also widely referred to in the literature from speculative and critical design, where prototypes (Mogensen, 1992), cultural probes (Gaver et al., 1999) or critical design objects (Dunne and Raby 2001) are used to challenge assumptions and provoke reflections on the impact of design solutions.

Specifically in the field of systemic design, Bijl-Brouwer & Malcolm (2020) highlight prototyping for their value in adopting an evolutionary design approach to desired systemic change. Studying teams of practitioners targeting systemic change, the researchers acknowledge the role prototypes played in reframing, one of the above-listed systemic design principles. In their study, they note how the prototypes evolved as the teams involved in the design process reframed the problem and developed further possible solutions.

Reframing is only one of the above-listed principles. We hypothesise that exploratory prototyping can play a significant role in operationalizing this emergent design practice. We believe that the capabilities of exploratory prototyping – e.g. the physical (re)assemblance of actors, artefacts, practices and outcomes; the probing of complex situations; the tangible support of idea generation and exploration – can significantly contribute to ease systemic design processes. In this study, we pose the following research question: how are key principles of systemic design activated through exploratory prototyping? 3. Methodology

3.1 Methodological approach

This study follows an abductive approach, drawing on theoretical and empirical inputs (Van Maanen et al. 2007). Our study is based on a series of research through design (RtD) experiments (Bang & Eriksen 2014; Frayling 1993). RtD allowed us to examine our research ques-

tion from the experimental action and tangible outcomes (Koskinen et al. 2011) of the experiments. Aiming at understanding the unfolding of systemic design principles through the practice of prototyping, we implemented design experiments to generate insights on the method through practice (Brandt & Binder 2007). Such experiments took the form of workshops. They lasted between two to three hours and invited three groups of participants (design students, researchers and practitioners) to engage with exploratory prototyping to address systemic issues in urban contexts.

The authors' embedded position in the experiments contributed to the generation, collection and analysis of rich qualitative material through participant observation (Czarniawska 2012). We also performed open-ended questionnaires (Züll 2016) and follow-up interviews (Trochim et al. 2016) to capture participants' perceived value of prototyping and materiality in the systems design process.

3.2 Research context

In the workshops, participants were presented with a design brief targeting complex urban systems. For example, in the first workshop, the participants had to prototype sustainable solutions for a traditionally-industrial area of the city of Lodz (Poland). The area is affected by a complex challenge: undergoing a new urban renovation plan for historical buildings, it is harmed by environmental issues, such as water flooding and air pollution. Near the city center, there are numerous political, environmental and social interests at stake in the area, making it a complex system to intervene.

The activities involved applying exploratory prototyping in the early stages of the design of solutions for transforming such complex urban systems. Table 2 provides an overview of the design activities and the use of exploratory prototyping.

Table 2 *Generic agenda of the design experiments with the design activities performed*

Activity	Description
Opening	Facilitators introduce the topic and the context of their research.
Introduction to the brief	Participants are introduced to the brief and the challenges of the urban context to be addressed.
Rounds of exploratory prototyping	Teams of participants are given materials and instructions to represent the targeted system in several rounds of exploratory prototyping targeting the material infrastructure, the socio-technical factors, the environmental factors, economic and political elements; the human and other-than-human actors, and the flows and interactions between them
Envisioning solutions	Participants generate prototypes of potential solutions that lead to their targeted vision for the system

Plenary discussion	Round of presentations followed by reflections on the use of exploratory prototyping for complex systems
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We conducted three cross-context experiments to understand the generalizability of the results in different contexts and with different sets of participants (Blair and McClendo 2021). Two experiments occurred in an academic context: one as part of a design conference, the other in a service design master class. The last one was part of a seminar where both academics and industry professionals participated. Table 3 summarises the design experiments and their characteristics.

Table 3 Overview of the design experiments

Context	Goal	Participants	No. of participants	Date	Duration
Academic conference workshop	Conceiving sustainable solutions for the urban renovation in the area of Księży Młyn (Lodz, Poland)	Design researchers and practitioners	18	July 2023	2 hours
Academic teaching workshop	Imagining alternative business ideas for sustainable challenges affecting the city of Copenhagen (e.g. overconsumption, fossil fuels, migration)	Service systems design master students	30	September 2023	2,5 hours
Public seminar	Envisioning future concepts for Anon, a cultural activist centre in Malmö (Sweden).	Architects, designers and design researchers	11	September 2023	1,5 hours

4. Findings

In the following, we present our analysis of the three experiments focusing on the role played by prototyping in the systemic design process and how prototyping unfolded the principles of systemic design described in section 2.1.

4.1 Acknowledging and appreciating the system's complexity

When asked about the influence of prototyping in the design process, the majority of participants emphasized its role in understanding the system's complexity and, hence, strategizing on how to better act on it: "We had a better understanding of the whole system that is behind the challenge [...]. We also broad[ened] our perspective and got a more holistic vision of the stakeholders involved. By doing this, we were able to decide on which area of the whole system it was more interesting to work with". As pointed out by the publications on

systemic design studied in this paper, the participants acknowledged prototyping as a way to develop empathy with the system. In their words, "it was a way to make our thoughts tangible and to actually visualise all the small details which influence the system. It was a way to recognise the factors, the cause and the consequences of each flow, helping us what was the actual problem to solve and what the existing resources we could use".

In particular, prototyping was highlighted for helping "visualise the abstract problem into something tangible to work with". This visualisation contributed to making their ideas "easier to relate to", expand their "perspective on certain areas of the system" they were not aware of, and pay more attention to the "environment affected by their solution". For example, picture 1 belongs to a group that worked with the interrelated challenges of waster in the city and overconsumption. When prototyping, they started from materializing a shop, which then lead to unfold and represent the supply chain of products and their after-purchase life. In this way, they uncovered more specific challenges in the system and planned a portfolio of solutions to alleviate them.



Picture 1 Representing the system through exploratory prototyping helped participants to visualize the complexity they were working with and conceive solutions to act on it

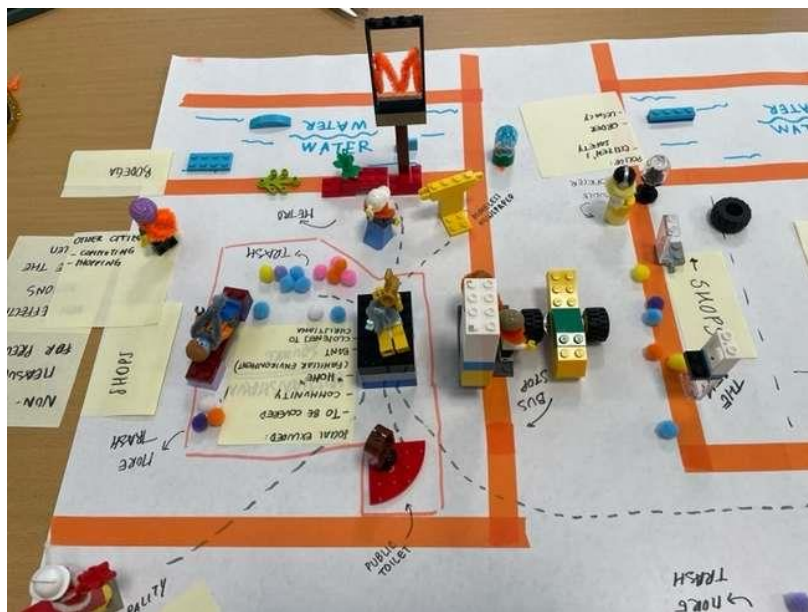
Aligned with Drew et al. (2021), the participants also mentioned their work on different scale levels when describing their experience with prototyping, moving from their initial (and more familiar) micro level to the macro and meso levels: "by prototyping and visualising it out, it highlighted that there were other parts of the bigger picture we wanted to work with".

Several participants agreed that this initial activity helped them overcome a common feeling of intimidation when addressing systems. This fear of not-doing due to lack of knowledge or skills when facing something perceived as intricate resonates with Murphy's research (2022), which warns of the risk of indeterminism when dealing with systems. System understanding and system thinking were perceived as challenging and impossible due to their complexity, but participants recognised the value of building and thinking through the represented system.

4.2 Recognising interrelatedness

The perception of the dependencies and connections among the system's elements was one of the most repeated values among the workshop participants. They reported that prototyping "helped to identify stakeholders, connections, flow and interactions" (picture 2) and "sparked discussions and conversations about the bigger picture and the connectedness of everything".

As a consequence of recognising the interrelatedness of elements in the system through their prototypes, participants actively considered the necessity to adapt their design approach and generate tailored solutions that functioned in the intricate systems they were addressing. In practice, they realised that when altering one piece in their prototypes, many others were affected: "We realised it was incredibly difficult to change any part of the flow of production because they were strongly interconnected with the previous and following pieces of the production flow of a product."



Picture 2 Exploratory prototyping helped to identify connections between elements of the system and, consequently, those elements that would be affected by proposed design solutions

4.3 Framing or reframing the system's boundary

Prototypes enabled participants to deliveratively consider the boundaries of the system they were addressing. Jones (2014, p.17) describes reframing as "an abductive reasoning process of identifying new metaphors and a 'better problem' to resolve than the issue as given in the brief". Participants from the three workshops recognised that prototyping in their teams facilitated the necessary discussions on the problem they were facing.

One of the groups depicted the targeted system as a human body. They represented a heart, a brain, hands, and lungs, generating analogies between the organs and the different parts of the urban context. As they explained, thinking of the urban system as a human body compound of organs with specific functions that also operate together in a bigger system enabled conjectures on innovative ideas and a shared understanding of the necessity of developing solutions that performed on the individual level and in coordination for a bigger cause. For example, the group asked themselves about the lungs, rising questions on how to ensure that the urban space could breathe and re-oxygenate (Picture 3). In that manner, they uncovered some lacks or needs within the system that they could act upon. Later, while presenting their proposals, they considered the urban system as a whole body, reflecting on how certain solutions would affect other "organs".



Picture 3 A team used the metaphor of a body to explore the urban system they targeted and identify potential challenges to address.

Building a tangible representation of the problem area facilitated the teams to identify the issues at stake and acknowledge the opportunities and resources to leverage from. Another team became aware of the storage spaces available that could become an asset to consider

in their design of solutions while prototyping: "For the [solution], it was really demonstrating to prototype the city and the buildings with all their storage, because it helped us see [how] that space could be used in something else and it helped us get more inspiration".

For this group, the representations contributed to identifying leverage points (Meadows, 2008). For others, like the human-body group, prototyping triggered a creative perspective on the addressed challenge. In both cases, prototyping supported collective thinking on the problem space, one of the principles described in the studies on systemic design by van der Bijl-Brouwer and Malcolm (2020) and Jones (2014).

4.4 Establishing a vision for the system

During the workshops, participants used prototypes as part of a system transformation process. One of the main problems the teams faced was establishing a new purpose or vision for shifting the targeted system. Framing a new purpose is invariable for any systemic design process and, according to Leadbeater and Winhall (2020, p.32), "involves argument, challenge and dispute as well as imagination, vision and inspiration".

As facilitators, we observed how, while prototyping the current system, some questions and issues emerged and prompted the teams into discussions and arguments on the future vision of the system they pursued. In the act of representing the system, some teams already set the focus on materializing their future vision of it. For example, in a workshop, one team focused on the public spaces in the urban ecosystem in their prototype (picture 4). The team dialogued on the role of those common spaces as enablers of certain values they wanted to promote in the urban system they envisioned. One of the members introduced the ideas behind "governing the commons" from Elinor Ostrom (1990). Together, they adopted the concept of "commons" in their design process as their vision and imagined design solutions that leveraged spaces with a strong sense of "commons" for the future of the urban system.



Picture 4 A team prototyped their vision of a system, envisioning solutions according to Elinor Ostrom's concept of "governing the commons"

Participants also acknowledged the influence of prototyping in supporting envisioning processes. Particularly, some expressed that prototyping was useful when "thinking about alternative directions" and imagining together "more vividly their visions for the future" as a departure point for ideation. They reported that collaborative prototyping was "a good way to base ideating on some clear visions, rather than coming up with the idea and then see if it solves bigger issues".

4.5 Concentrating on relationships

Systemic design targets change by concentrating on the reconfiguration of actors in ways that generate behaviours that align with the values envisioned for the system. The physical representation of actors in prototypes placed them all on the table. In this way, the perception of the existing relationships among actors that could be reconfigured in new ways became more palpable: "[prototyping] helped me understand the relationships between stakeholders and [...] gave me a clearer idea about how the actors (stakeholders, companies...) create environmental impact and what potential solutions we can provide".

This attention to relationships was reported by participants as one of the main contributions of prototyping in their systemic design process. The tactile aspect of prototypes generated a different intimacy with the stakeholders in the system, both human and non-human actors, institutions, etc. When considering the impact of understanding the relationships in the design process, some participants reported its influence on problem framing and idea genera-

tion: "The prototype helped to analyse various connections between actors (both non-human and human), and this analysis helped to define potential users and an interesting problem area for the group".

4.6 Promoting multifaceted strategies to enable change

The solutions proposed by the participants reflected strategies for transforming the targeted systems based on some of the concepts mentioned in the three reference studies of this paper. Several teams' solutions leveraged strategic aspects of the system that could have a transformational ripple effect in the system. An example of this could be the team that leveraged existing abandoned storage spaces in the city for more sustainable use of resources and circular urban ecosystems (picture 5).



Picture 5 Prototyping the system revealed the storage spaces available that became an asset of their solution.

In another workshop, a team proposed a program of solutions spread over the urban space, a compound of different initiatives that activated the values they envisioned for the new city. For the future of a cultural venue in Malmo, they represented the venue as a "guiding lighthouse". The lighthouse would hold the values the cultural venue stands for, and "illuminate" several initiatives all over the city to activate or work towards such values. In their prototype, they represented the lighthouse surrounded by randomly arranged pieces in the urban space (picture 6). Throughout the workshop, they brainstormed what some of those solutions could be. However, in their presentation, they emphasized that their main outcome was the strategy of a distributed network of activities guided by the values of the cultural venue for a larger impact scope. Their ideas grounded on what van der Bijl-Brouwer and Malcolm (2020) described as influencing mental models through tangible interventions to enable change. In the words of one of the participants: "Our idea revolved around how we could create a safe open space to generate change inside but also influence the 'other space'. The things created inside will make a difference out there".



Picture 6 The team explored the vision of a cultural venue becoming a lighthouse (center) “illuminating” a network of activities, elements or institutions supporting similar values across the city

5. Conclusive discussion

This paper explored the following research question: How does exploratory prototyping activate key systemic design principles?

The findings described in the previous section show that exploratory prototyping can be an asset for systemic design. Both participants and facilitators of the workshops acknowledged the influence of prototyping in unfolding the systemic design principles identified in the literature. Out of the six principles, participants openly appreciated prototyping's influence in the activities of (1) acknowledging and appreciating the system's complexity, recognising (2) interrelatedness and (3) relationships within the system. From understanding the system, its elements and connections, they reported that prototyping also facilitated the subsequent activities of (4) framing the system's boundaries, (5) establishing a vision for the system, and (6) developing solutions to enable the envisioned change.

Even if there is no widely accepted systemic design methodology, we can use the one proposed by Jones and van Ael (2022), as one of the most extended, to reflect on the impact of the workshops' results for the systemic design practice. The results from the workshops show that the use of exploratory prototyping could facilitate some of activities in the earlier stages of the processes, such as Framing the System, Understanding the System, Defining the Desired Future, and eventually, Exploring the Possibility Space. The results, however, do not shed light in the contribution towards Listening to the System, Planning the Change Process, or Fostering the Transition. This probably has to do with the type of prototyping logic that was used. Exploratory prototyping provided teams with a tangible way to materialize

the complexity of the system and abstract connections and relationships that eased collaborative imagination processes towards potential alternatives in the system. Resonating with the words of Snowden and Rancati (2021), the findings of this study accentuate the value of prototypes as tools for exploring the “invisible adjacent possible”. These values align with the needs and demands of divergent activities in the design process. On the contrary, one could speculate that a traditional prototyping logic would probably find a better fit in the latter stages, more oriented to the convergence of solutions and their implementation in the system. But a different type of study would be needed to shed light on such hypothesis.

The combination of rationality and tactility seemed to be the added value of exploratory prototyping in the studied processes. The observations and testimonies collected during the three workshops demonstrate that exploratory prototyping promoted embodiment processes that supported design work on the system, such as the use of metaphors, sensorial engagement with the system, and the construction of conjectures on possible futures. Prototype’s inherent palpability facilitated collaborative thinking processes on complex and abstract ideas. It was in the act of building together where the learning and exploration occurred, rather than in the operation of the final prototypes afterwards.

Traditionally, prototypes are valued for their validating capacity. They are objects (conventionally shaped by one expert designer) that we learn from after they are built and that inform us about the object that is being built. In this case, the prototypes informed participants about possibilities, alternatives, deficiencies, and opportunities within the system. Countering the object-focused learning aspect with a “mutual learning” aspect, prototypes became intermediary objects between participants and the context (Suchman 2002). In the workshops, the prototypes functioned almost like boundary objects (Star and Griesemer 1989), embodying knowledge that was only activated during the act of collective building of the object. Like boundary objects, prototypes carried knowledge that was only activated through dialogue. The prototypes needed to be discussed and interpreted by participants to generate meaning. This function of prototypes resonates with DiSalvo’s work on critical making, where he describes prototypes as “dialogic in that its structure is one of exchange and its purpose is the discovery and elucidation of the conditions or factors of a design” (2013, p.23).

The complex and abstract nature of systems commonly paralyses or prevents their transformation. Exploratory prototyping offered participants a new language to decipher and navigate such complexity. Nevertheless, prototypes are, ultimately, practitioners’ interpretations of the system elements. That is, prototypes are simplifications that allow comprehension and operation. Yet, simplifying entails adding boundaries within the system, restricting the area of attention, and losing the perception of the entirety. Both prototypes’ strengths and limitations rely on simplification. While the tactile representation eases the difficulties of approaching systems, it also comes with the risk of (over)simplifying the complexity at stake. This paradox, which also affects other tools and methods in systemic design, should be considered when applying exploratory prototyping in systemic design. Instantiating a space for tensions to emerge is one of the values of exploratory prototyping, but practitioners should

be aware of what is excluded from the prototype. Systemic design principles are one possible strategy around this ambiguity, orienting practitioners to find a balance between simplification and complexity.

In conclusion, our research expands our understanding of the use of exploratory prototyping to activate some of the key systemic design principles. The intrinsic exploratory nature of prototyping can be applied to the early stages of the systemic design process to ease the understanding of the system characteristics, support multiple views on the framing of the problem and the establishment of new visions, and facilitate the design of deliberate actions for the envisioned change.

A limitation of our work may be in the list of principles of systemic design. This list should not be understood as exhaustive but rather as an initial attempt to compile the characteristics of the systemic design practice from comparing previous research. Potentially, other studies should be included and contrasted.

Another limitation lies in the workshops used in this study. On one hand, the number of controlled experiments makes it difficult to generalize the findings. On the other, the format of the workshops obliged participants to go through a fast-paced systemic design process (or, at least, to the early stages of it). As exploratory prototyping in systemic design is still in its infancy, we used the controlled environments of workshops to generate primary answers to our research question. However, we contend that future studies could benefit from an analysis that examines exploratory prototyping in a "real" systemic design process.

We acknowledge that our findings are preliminary, and further research is needed to validate them in different scenarios. Also, the results of the workshops were not analyzed in relation to participants' backgrounds, an analysis that could lead to tailor the understanding on the use of prototyping in systemic design contexts. Nevertheless, this paper is an open invitation to reflect and forward our thoughts and understanding of prototyping in systemic design processes.

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