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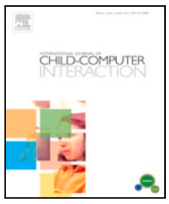

Research paper

Social imaginaries as a lens on co-designing environmental sustainability

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ABSTRACT

Social imaginaries are a way of envisioning how people maintain society, and of understanding what is valued within that society. In this project, we worked with children on environmentally sustainable solutions for the future using co-design, a common methodology in child–computer interaction. We apply a social imaginary lens to five co-design case studies, from different geographic regions around the world, to describe and analyze variations in design practices as well as in design artifacts, and examine the ways in which children demonstrated a shared understanding of a pro-social world. The primary contribution of this paper is an illustration of the use of social imaginaries for interpreting and organizing co-design around environmental sustainability.

1. Introduction

Responding to the special issue call on the role of child–computer interaction (CCI) in supporting children's engagement with environmental sustainability at a time of climate crisis (Vasalou & Gauthier, 2023), we describe how five co-design case studies on environmental sustainability were analyzed using a lens of social imaginaries. We then contribute ideas on how social imaginaries could be applied in other aspects of co-design practice with children. The term "social imaginaries" refers to the collective understandings, shared beliefs, and visions that shape the way people perceive and organize their societies (O'Neill, 2016). Rather than being individual concepts, social imaginaries represent shared constructs that influence how communities interpret their experiences, interact with one another, and understand their role in the broader world. In climate change research, such imaginaries have been used to facilitate conversations about change as well as being used to help design solutions (Milkoreit, 2017). Given the collective nature of social imaginaries, one might hypothesize that they would be an interesting lens to apply to co-design practice.

Engaging children in environmental sustainability and climate change brings challenges; on the one hand, as agents of change, children need to be engaged with Horton, Hadfield-Hill, Christensen, and Kraftl (2013), while such engagement needs also to be hopeful and there needs to be caution in not overwhelming children with catastrophic messages. Strife (2012) emphasizes this role and calls for more participatory, child-centered approaches in sustainability efforts. In this context, child–computer interaction (CCI) can significantly enhance children's capacity to engage with environmental sustainability by providing interactive tools and platforms that empower them to take meaningful action and develop a deeper understanding of their role in fostering a sustainable future. Vasalou and Gauthier (2023) emphasize the importance of designing child-centered, participatory technologies that foster environmental awareness, critical thinking, and action, while acknowledging the emotional and cognitive challenges children may face in confronting the climate crisis.

In our work, we built on prior research on distributed participatory design (DPD) (Constantin et al., 2022), by conducting five distinct co-design projects with children across five countries, all based on a unified research protocol centered around the theme of climate change. This work also builds on related work that explored the management and analysis of cross-country distributed co-design research

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(Read et al., 2024). In this present article, we examine the processes and outcomes from the same five studies through the lens of social imaginaries, identifying the ways in which social imaginaries were manifested in our co-design process and also how they were seen in the artifacts created by children, which provided evidence that they not only engaged with the fantastical, but also worked towards designing more practical, sustainable futures. Our research question in this analysis was: to what extent and in what way can the concept of Social Imaginaries provide a useful lens for understanding children's co-design sessions to support environmental sustainability?

As noted above, we did not intentionally use a social imaginaries framework in preparing the design sessions, however, we present an analysis of these design studies as case studies through the lens of social imaginaries. This analysis includes describing how we interacted with children, the materials used, how problems were framed with the children, and the prototype outcomes, which ranged from drawings to paper prototypes to Lego robots. We believe our reflective analysis of co-design through a social imaginaries lens provides evidence to support a more intentional use of social imaginaries in co-design with children.

2. Background

To contextualize this work, we present a brief overview of participatory design including distributed participatory and facilitation practices, and social imaginaries as related to participatory design.

2.1. Participatory design and distributed participatory design

Participatory design (PD) is a philosophy and approach to the design of new technologies that is centered on the involvement or participation of end users in the design process (Bødker, Dindler, Iversen, & Smith, 2022). Its roots are found in basic values of democracy, such that "people who are affected by a decision or event should have an opportunity to influence it" (*Participatory Design: Principles and Practices*, 2017), which is especially important when it comes to environmental sustainability and future generations. In the research literature, participatory design with children is common (e.g., Read et al. (2024), Druin (1999), Fails, Guha, and Druin (2013)), in part because of its positive effects for children; PD is an empowering experience for children, giving them self-esteem, confidence to share opinions and ideas with others, and opportunities to develop new skills, such as collaboration (Guha, Druin, & Fails, 2010; Malinverni et al., 2014; Hussain, 2010; Korte, Potter, & Nielsen, 2017).

Distributed participatory design (DPD) refers to PD in which "all or most [of the] design team members are physically and perhaps temporally dispersed" (Constantin et al., 2021). In DPD the activities in the session may be created by the design team but facilitated via a proxy, such as a teacher, or mediated through technology. DPD unlocks potential for PD to address 'bigger picture' goals, such as environmental sustainability, with co-located or distributed teams able to collaborate together on larger projects.

Although there are multiple approaches to user involvement in PD (Vines, Clarke, Wright, McCarthy, & Olivier, 2013), a widely applied strategy is the use of facilitated activities, typically organized and led by a PD facilitator. A PD facilitator can be characterized as a person with theoretical and methodological competence in PD, often in combination with technical knowledge (Dahl & Svanæs, 2020; Light & Akama, 2012; Slingerland, Murray, Lukosch, McCarthy, & Brazier, 2022). The PD facilitator role goes beyond mere coordination, as PD facilitators can also be considered responsible for embodying PD's guiding principles of democracy, user empowerment, mutual learning, and the appreciation of human skills (Dahl & Svanæs, 2020). While originally designed for face-to-face delivery, PD facilitation has moved towards a distributed format, which entails exploring new methods, materials, and activities for distributed PD (Slingerland et al., 2022; Obendorf, Janneck, & Finck, 2009; Winschiers-Theophilus, Goagoses, Rötkönen, & Zaman, 2022a).

PD facilitation is a reflective practice, inspired by Schön's (Schon, 1984) theories of reflective practice, which consider both on-action and in-action reflection as key steps towards professional development. Slovák, Frauenberger, and Fitzpatrick (2017) argue that Schön's lens of the reflective practicum can serve as a guide for designers aiming to develop a technology-based system or activity for transformative reflection. In order to support this, they have developed a conceptual framework that extends the concept of the reflective practicum towards identifying appropriate roles of technology to support transformative reflection. In Schön's apprenticeship contexts, the mentors played an instrumental role in facilitating meaningful teachable moments through well-selected tasks, while at the same time providing modeling and in-the-moment scaffolding to help students make sense of the resulting experience through reflection (Slovák et al., 2017). According to Schön, this can happen through a combination of 1) involvement with a particular design case; 2) having their reflection scaffolded by the support from the mentor; and 3) doing so in a 'safe space' where experimentation was encouraged and effect of failure low (Schon, 1984). This means that the facilitator needs to scaffold for an experience that is real enough to be reflected on, but stays in a safe space where it is possible to do explorations. As Slovak et al. describe it, the activity can be characterized to include a tension between (i) eliciting emotions and/or experiences of interpersonal interaction that feel real, but at the same time (ii) are not too overwhelming so that they can still be approached with a learning mindset and reflected upon (Slovák et al., 2017).

In this article, we will focus on the ways in which social imaginaries relate to the scaffolding and facilitation of our varied co-design sessions.

2.2. Social imaginaries

As noted above, social imaginaries are a broad understanding of how people collectively imagine and understand their social existence (Phadke, Samory, & Mitra, 2021; Taylor, 2002). The concept of social imaginaries – broadly understood as the shared visions, ideas, and frameworks through which people collectively make sense of their social reality – has received increasing attention across disciplines, from sociology (Suckert, 2022) to cultural studies (Kølvraa & Forchtner, 2019) and design research (Lockton et al., 2019). These imaginaries are not just theoretical frameworks, but deeply embedded cultural understandings that shape everyday life, institutions, and practices. Social imaginaries are a way to understand how collective beliefs and cultural practices shape societies, often at a level below conscious thought.

Participatory design, which emphasizes the direct involvement of users and stakeholders in the design process, can serve as a powerful means of engaging with social imaginaries. While social imaginaries provide the cultural and historical framework that shape the context and aspirations of design, participatory design acts as a tool to materialize and transform these shared visions into tangible outcomes. Through this interplay, participatory design not only reflects existing imaginaries, but also fosters their evolution by enabling collective creativity and dialogue (Sivtseva, 2023).

When considered with children, the concept of social imaginaries takes on unique importance, as children's imaginaries can illuminate their perspectives on society, power structures, and their place in the world. By integrating social imaginaries, researchers and designers can better understand and respect the social and cultural contexts of children's lives. Examples of using social imaginaries in participatory design with children are found in projects that engage children in envisioning future technologies or community spaces (Druin, 1999; Guha, Druin, & Fails, 2011). Although these examples do not

Table 1
Overview of the cases.

Country	Context	Participants	Time	Theme
Denmark	Classroom Grade 6	22 children (age 12) Facilitator, Teacher, Researchers	2 × 90 min	Water rise
Romania	Classroom Grade 5 to 8	8 children (ages 12-15) Facilitator, Teacher, Researchers	1 × 90 min	Reducing waste
UK	Classroom Grade 5	40+ children (age 10) Facilitator, Teacher, Researchers	2 × 60 min	Re-use
USA	Cooperative Inquiry Team	7 children (ages 7-11) Facilitator, Researchers	3 × 90 min	Transportation
Australia	Classroom Grade 5	30 children (ages 9-10) Facilitator, Teachers, Observers	120 min	Waste and recycling

cite 'social imaginaries' as a concept, the emphasis is on scaffolding understanding of social and cultural environments (i.e., contextual understanding), prioritizing children's lived experiences, environments, and social interactions as integral components of the design process.

In cooperative inquiry, Guha and collaborators (Guha et al., 2011) – as well as many others who have adopted or adapted this framework – engaged children in the entire design process, from brainstorming to prototyping, allowing their imaginative ideas and social contexts to guide development. This approach aligns with social imaginaries by centering children's imaginative and social contributions in the design process. By engaging with the shared practices, values, and contexts that shape children's perspectives, the approach not only reflects children's existing social imaginaries but also empowers them to envision and co-create new possibilities for the future. In so doing, cooperative inquiry underscores the transformative potential of participatory design to align technology development with the collective aspirations of its users.

Co-design is generally touted as a qualitative way of improving designs and giving users an authentic voice in the design of technologies that they will use. Our experience co-designing sustainable technologies with and for children took things a step further by asking children to firstly imagine a future context of use, where the world is very different, and then to design for that imagined future.

3. Study - social imaginaries in co-design

Our initial work sought to explore the feasibility and possibilities of a single topic (climate change in this instance), multi-site DPD project by examining a small set of PD cases constrained by a grounding in a published DPD research protocol (Constantin et al., 2022). The study design championed differentiated replication by allowing for deliberate and known variations, including age of children, location of study, tools used, and approach taken. This design met the aims of multi-site qualitative research, which produces findings that are reflective of context, but hold broader applicability across settings (Jenkins, Slemon, Haines-Saah, & Oliffe, 2018).

Five case studies, from five countries on three continents, were chosen to be re-analyzed for this present study (see Table 1 for an overview); each had a unique facilitating team that included one or more researchers. In this current work, for this paper, the attending researchers reexamine these case studies, using social imaginaries as a provocation and a lens. Note that we refer here to all the young participants as children despite some being teenagers; this is for ease of reading.

3.1. Study design

We present a four-stage retrospective analysis of five design sessions through a social imaginary lens. The first stage (co-design process) involved each researcher / researcher team re-examining their case study to determine whether, and in what ways, social imaginaries were embedded within the design process. Given that each case study had the autonomy to structure activities within the available time frame and the children's capabilities, this post hoc analysis of whether elements of social imaginaries were inherently present was carried out in order to identify factors that foster collective creativity, shared values, and dialogue within the studies.

The second stage (designed artifacts) required each researcher / researcher team to examine the artifacts created by the children to identify shared values and beliefs. While prior CCI research has explored ways to integrate children's individual ideas into a single design (Read, Fitton, Sim, & Horton, 2016), these approaches typically focus on representing children's ideas rather than grounding the design in their culture, shared values, and beliefs; tending to prioritize representation over deeper engagement with shared perspectives.

The third stage (shared reflection) was carried out after all the initial analysis was completed; an online focus group of the researchers was convened, during which individual themes were discussed and merged into a list of five overarching themes.

In the fourth stage (theme identification), each researcher re-visited the process and artifacts from their own case looking for concrete examples of where, if at all, the themes were referenced.

This staged approach, using a social imaginaries lens to retrospectively analyze the five case studies, facilitates a critical reflection on the design process and the data collected. The study ultimately seeks to address how the concept of Social Imaginaries can provide a useful lens for analyzing participatory design sessions to support environmental sustainability.

4. Co-design sessions for sustainability: The cases

In this section, we share the five cases. In each case, we firstly present an overview of the specifics of the case describing in a factual way the co-design process and resulting artifacts, we then present an analysis of the case through the lens of social imaginaries, describing the ways in which these may have played out during the design process, and the ways in which social imaginaries were represented in the children's design and prototypes.

4.1. Case 1: Denmark – The water is rising!

4.1.1. The co-design event

Two sessions were held in a classroom in a school and were part of a scheduled course on technology comprehension and programming. The

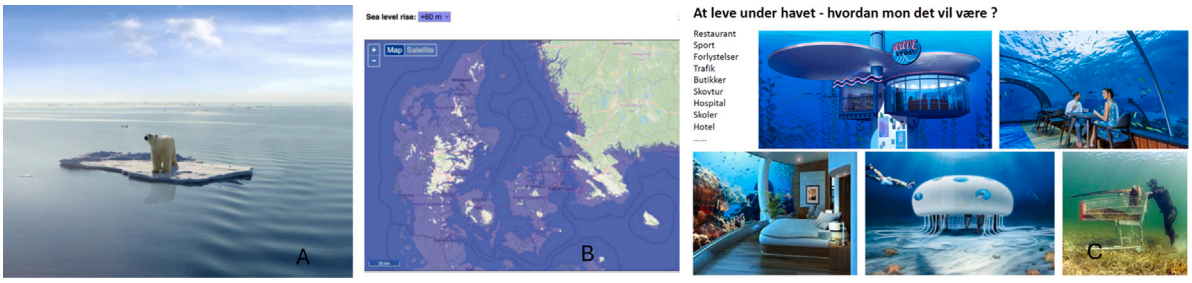

Fig. 1. Parts of the framing in Denmark, in which the water is rising due to climate crisis. The children are taken through a three stage journey: from (A) individual understanding of distant phenomena to (B) shared personal experience as their village sinks, and are asked to (C) imagine how they would now live under water.

facilitator for this case worked at the university, but visited the school every week, conducting teacher training in technology comprehension and programming. The researchers met with the facilitator to share the design protocol; then the facilitator designed the sessions, and provided materials including a Tinker Qube[1] to design around, Lego Spike robots, diodes, and various tinkering materials. The children knew beforehand, from their timetable that they would have a FabLab class.

The co-design sessions were designed as two, ninety minute sessions in a sixth grade class (age 12) of 22 children with a facilitator, teacher and researcher present. The teacher formed the groups. Since the study took place in class when the children had the school subject FabLab, the main learning goal was related to programming and tinkering with technologies, however, this was framed around "What is the impact of rising sea-levels?". In the first session, the facilitator started by introducing the setting and the problem. The task for the children was to construct underwater worlds, with the notion that the water is rising due to climate change, and their village will be underwater in the future. One researcher acted as an observer and assistant. In the second session, the children continued to construct their underwater worlds, but this time, the facilitator introduced the need to add moving underwater animals (see examples in Fig. 3). Three researchers acted as observers and assistants.

Photographs were taken of the designs, each of which showed some understanding of what it might be like to live underwater, although some practicalities could be considered to have taken second place to the aesthetics; e.g., TVs were co-existing with sea creatures in the designs. After the study, the researchers debriefed the facilitator. The facilitator was not satisfied with the outcome as he did not feel that the main objective of the activity (learning programming) had been met; however he was satisfied that the children had fun. The researchers concluded a relatively high level of engagement in the children, as well as a visible change in the children when they first experienced and then explored their village and homes under water (awareness of climate change).

4.1.2. Reflections on social imaginaries in the co-design process

It appeared that, in the framing of the task, the facilitator put significant effort into trying to elicit the children's imagination. He started out by showing a picture of a polar bear on floating ice, and asked what the children thought this represented (see Fig. 1). Quite quickly, the dialogue went into the topic of the climate crisis. He showed pictures of people trying to adjust to flooding, just to get some sense of what that means and showed a map of Denmark that illustrated what it would look like when the water rose 20 meters; the children were happy to see that their village was still intact, but a bit emotional that perhaps a village, where maybe a grandparent might live, might not exist anymore. The next image showed Denmark when the water rose to 60 meters, and suddenly the whole room reacted — their village did not exist anymore! It became personal: how should we live? how do we play football? where do we buy groceries? The facilitator moved on to show illustrations from children's literature on underwater worlds, and from generated future scenarios of under-water living, and he asked the children to start imagining how we would live, how we would create life under water.

Although this introductory session lasted only 15 min in total, the change in the children was visible. They went from an individual understanding of climate crisis as something distant and not relevant to them (although they felt sorry for the polar bear), to a shared social imaginary of the implications of climate crisis on their own lives. It was a powerful change that gave rise to many discussions and scenarios about future living.

4.1.3. Reflections on social imaginaries in designed artifacts

The prototypes showed signs of social imaginaries in various ways (see Fig. 2). Typically, mundane everyday life was reflected in the prototypes, where we see indoor soccer fields, basketball courts and ordinary homes — although under water and with deep-sea creatures passing by outside. However, there was also an instance of a hotel, to make sure that visitors to the village could have a safe stay, even though the village was under water. The social imaginary of the children showed signs of building resilience when the environmental crisis hits us, and not giving up.

4.2. Case 2: Romania – A treasure hunt for recycled garbage

4.2.1. The co-design event

This study took place in one session in a village school in Romania and lasted for 90 min. The facilitator was an undergraduate student in Computer Science with an interest in Human-Computer Interaction. A researcher met with the facilitator to present the research protocol and the study design. The facilitator and the researcher discussed and amended the study plan and prepared the materials and a presentation. The presentation aimed to introduce the main concepts related to climate change, explaining what causes this phenomenon and how it impacts our Earth. The team consisted of eight children, aged 12 to 15, and four adults (the researcher, the facilitator and two teachers who played the roles of observers and assistants). First, the facilitator delivered the presentation and encouraged the children to ask questions. After that, a design brief was introduced, requiring children to use their imagination and draw or write ideas for how technology can help children like them learn about reducing waste. Children received pencils, blank sheets of paper, paper notes, and relevant images to be used in the design activities. None of the children requested help and the facilitator only passed by each child to assure them that their work was appreciated. After about twenty minutes, the children were grouped into two teams. Each child presented their work to the other team members, discussing their ideas, and then each team was encouraged to create a poster for a game by combining all the ideas. At the end, each child answered a brief questionnaire with three 5-Likert scale questions and five open questions regarding their experience during the study. All the children managed to contribute ideas. The

[1] See https://www.upfind.dk/

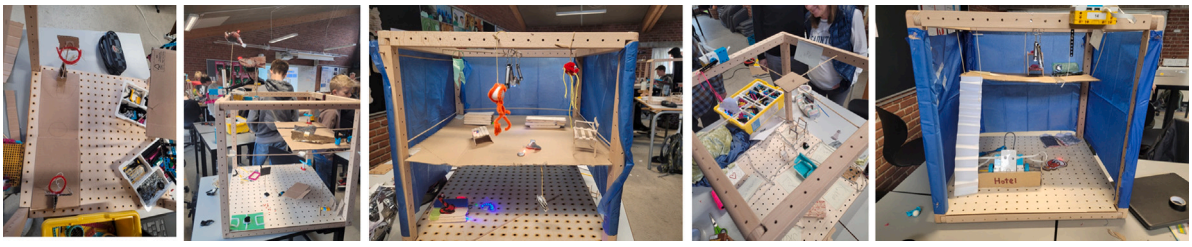

Fig. 2. At-home sports - DK1 basketball, DK2 football. DK3 and DK4 are ordinary homes under water, while DK5 is a hotel.

Fig. 3. Parts of the social imaginary in Rusanesti (Romania). The children are exposed to a three stage short presentation: (A) Climate change (B) Plastic pollution (C) Food waste.

group activity proved problematic, as none of the teams managed to build a poster for a shared game. That may be because these children did not have many opportunities to work in teams in their school, as they declared. The facilitator, the researcher and the observers noticed that almost all children had a high level of engagement and interest throughout the study. Also, they observed that after working on the design and reflecting on what they had learned, some children became more aware of the importance of reducing waste and started thinking of practical ideas for their village or homes.

4.2.2. Reflections on social imaginaries in the co-design process

To frame the task, the facilitator delivered a concise, visually-supported three-stage presentation designed to spark discussion and imaginative thinking. Each stage progressively connected abstract concepts, like climate change and its global implications, to specific environmental challenges and actionable steps. In the first stage, children were introduced to broad concepts, such as climate change and then encouraged to reflect on questions like: Should we care about the consequences of global warming? How does climate change affect our daily lives? What can we do daily to help the planet? The second stage focused on specific environmental issues, such as plastic pollution, linking these to everyday actions and choices. Finally, in the third stage, the presentation highlighted practical, actionable steps, such as reducing food waste, that the children could apply directly in their homes and communities.

This structured approach helped children gradually understand complex topics, making it easier to see how large-scale issues connect to their daily lives and actions. The presentation had a notable impact on the children's understanding of these concepts. Initially, there was some hesitation about the importance of climate change and whether children like them should be concerned. When asked, "Should we care about the consequences of global warming?", one child commented that it seemed like a responsibility for government leaders to handle through laws and actions, questioning what role children could realistically play. However, in the end, the children recognized that everyone can contribute to addressing climate issues, including reducing plastic pollution and food waste. The initial view shifted, that the problem was too complex for children and ordinary people to address. The children developed a shared social imaginary that enabled them to realize even minor contributions could create a ripple effect, ultimately supporting larger environmental goals.

4.2.3. Reflections on social imaginaries in designed artifacts

The children's descriptions varied in their emphasis on creativity, real-world action, and narrative elements, but they all shared a common vision of using playful yet impactful approaches to address global environmental challenges. Their responses revealed several social imaginaries centered on environmental care, collective action, and the role of technology. Some example artifacts can be seen in Fig. 4.

Environmental actions were framed as collaborative and emotionally meaningful, deeply linking personal efforts with global outcomes. Emotional and social values, such as empathy, kindness, and care for nature, formed the foundation of this vision, underscoring the importance of building meaningful connections with people and the planet. Through participatory design, children envisioned environmental responsibility as a shared and empowering journey, one that harmonizes creativity, individuality, and collective global goals. This vision was further reinforced by their innovative design ideas, which blended digital and real-world experiences.

All children contributed ideas using different methods. Two utilized text, drawings, and images; two used drawings and text; and the remaining four relied solely on text. Among them, five children articulated clear goals for their games, such as collecting and recycling garbage, learning ways to reduce pollution, raising awareness about the struggles animals and plants face due to pollution, and creating a cleaner world. One child suggested a concept similar to Pokémon GO, envisioning a game that could be played outdoors in parks or green spaces. Several children incorporated rewards, characters, plot twists, and fun as essential game elements.

However, group activities proved more challenging. Neither team managed to create a cohesive poster. One group presented a set of features for a game, while the other focused on discussing individual ideas without consolidating them into a shared outcome. Despite these challenges, the children's contributions reflected an enthusiastic and imaginative engagement with environmental issues, highlighting the potential place of participatory design and social imaginaries to inspire innovative solutions.

4.3. Cases 3: United Kingdom – Re-use do not recycle!

4.3.1. The co-design event

This event was held in a UK Primary School with children aged 9 to 10. Forty children participated in one of two versions (sessions) of a 1 h design activity one afternoon at their school. Before the study,

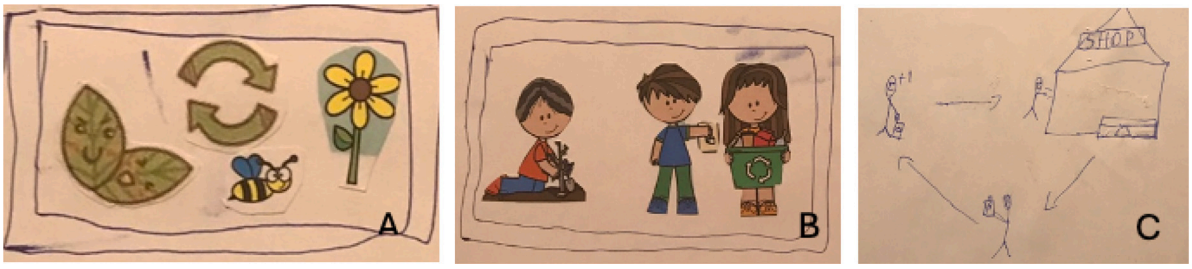

Fig. 4. Samples of the Romanian children's ideation: (A) Characters in the game; (B,C) Game activities.

the teacher and one of the two researchers independently designed the sessions. The children were all in the same school year and were in one of two class groups. The objective of the session was for children to understand the concept of re-use and how technology can be applied to this problem. The brief required the concept to be introduced to the children, followed by a design activity which the children would draw ideas and describe their drawings.

Two different facilitators (a teacher and a researcher) ran the two sessions and a second researcher acted as an observer and made notes. act as an observer. Both sessions started with an introduction on the topic for approximately 10 min, then the children worked on their designs individually. The two facilitators scaffolded and framed the sessions differently; the teacher took the approach of creating a mind map on a whiteboard, capturing some of the children's initial ideas about reuse. This approach invoked the children's imagination with lots of initial ideas on the concept, and she tried to tease out more ideas from the children that she felt were missing. In contrast, the researcher framed the discussion around reuse starting with a plastic cup and a jar to explore the concept, then briefly talked about technology and how this could potentially be reused.

Children handed in their drawings of technology solutions that might encourage re-use rather than recycling and the facilitators also captured their experiences in a short de-brief.

4.3.2. Reflection on social imaginaries in the co-design process

In the session lead by the teacher, imagination was encouraged through the inclusion of tools like mind maps and with an open discussion with the children. There was not a specific focus on how things might look in the future — the discussion was primarily focused on possible technologies. As some of the children struggled to get started, the teacher mentioned a robot as a possible solution which resulted in more than half the children then drawing robots. Reflecting on this from the perspective of social imaginaries it was clear that the framing constrained the thinking about the application of designs. The second session was constructed more in the social impact of recycling. The second stage was for children to think of questions and here they struggled to situate their ideas, the teacher had to help children get going. For both sessions, the limited time available and the need to structure the activity in a class session potentially lead to a mainly tech-centric design process. In future work, the addition of social context as well as more groupwork might have brought more social reflection and more contextual thinking to the activity.

4.3.3. Reflections on social imaginaries in designed artifacts

To explore the designs in the context of social imaginaries, seven UX students were given a short explanation of social imaginaries via the work of Lotz-Sisitka (Lotz-Sisitka, 2010) and Millei & Lappalainen (Millei & Lappalainen, 2023) and were then asked to examine the 51 children's drawings one at a time using an adapted RAId (Read et al., 2016) sheet with the constructs of 'Environmentally friendly construction' (to see if, even when thinking about reuse the children might also think about the build of their reuse ideas), 'Applies to reuse' (to establish if the design was related to reuse), and 'Child Friendly' - which needs no explanation. The UX students rated each design they saw with a score of 5 (definitely), 4 (Mainly), 3 (so-so), 2 (not much) and 1 (Barely) against each of those constructs. Having seen 7-8 designs, they were each asked to distill what the design they had seen told us about the social imaginaries of children (see Fig. 5). The children's designs varied substantially, with some having a lot of detail and others being hard to make sense of (see Fig. 5). In the image on the left, children were advocating to "save the world together" and the use of technology to achieve this objective. In the image on the right, children planned to raise money to plant trees to improve the environment. Overall, we found that the children thought of big, creative, ambitious ideas, with little concern for cost, and their designs reflected their perspective on society, which was binary — things being good or bad. They were not so clear about reuse, but they certainly understood environmental concepts. They saw technologies (especially robots) as important to save the environment, with solutions including robots, recycling, litter picking, and tree planting. Many children focused on planting trees and explored innovative ways to help in that.

Considering the number of drawings allocated by the students in the RAid analysis, the process encouraged the evaluators to look at the designs in different ways rather than to generate any specific insights. It appeared (from lower scores) that the designs were less focused on reuse than on general environmental and child-related things. This was re-iterated by the UX students in their comments.

4.4. Case 4: United States of America – sustainable transportation and leisure of the future

4.4.1. The co-design event

Three, 1.5 h co-design sessions were conducted with children in an intergenerational design team consisting of children (ages 6-11) and adults that utilized the Cooperative Inquiry method (Druin, 1999; Guha, Druin, & Fails, 2013; Fails et al., 2013). One session was conducted in 2023 and two were conducted in 2024 with different teams. All sessions were conducted in a child-friendly university space where children participated in design activities twice a week during the school year as an after-school activity. In all, fourteen children participated in these design sessions. The focus of the sessions was on ideation of future sustainable transportation (two sessions; one in 2023 and another in 2024) and what a sustainable vacation of the future might look like (one session; in 2024). The facilitators and researchers for these sessions included a co-design researcher with 20+ years of experience as well as undergraduate and graduate students. A total of ten adult researchers participated who had varying levels of experience with co-design (ranging from a few months to four years of experience). The adults ranged in experience from one to four years of experience on the design team. The context and purpose for the design activities was described by the most experienced facilitator. After an initial conversation as a full group (of 6–9 children and 4–7 adults), smaller groups were organized with each smaller group consisting of 2–3 children and 2–3 adults. The small groups used arts and crafts (for two of the sessions)

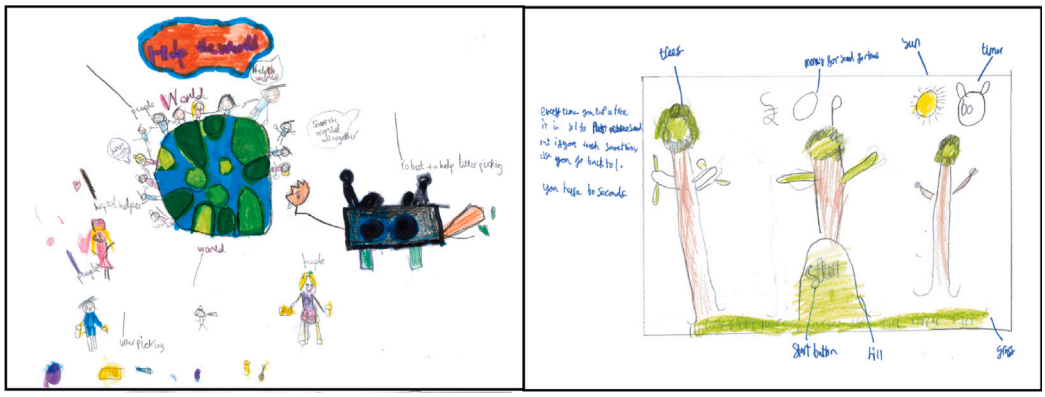

Fig. 5. Sample drawings created by the children in the UK depicting robots and plants.

and drawing (large format paper and/or whiteboard) to illustrate their ideas and create a shared artifact to discuss and elaborate on each others ideas.

The first session's artifacts consisted of drawings on a whiteboard and individual summaries of what each child thought transportation would look like in the future. During this session, the children and adults divided into four small groups to design the sustainable transportation of the future. Interestingly two of the groups envisioned the social imaginary that was conveyed that transportation might need to look different in order for it to be sustainable, and two focused on just the transportation of the future. There were apparent contrasts between the two approaches. The groups that focused on future transportation methods without the additional sustainable context provided by the social imaginary of current transportation methods impacting the environment came up with very fantastical ideas, resulting in designs such as individual self-driving, flying cars and jet-packs powered by compressed air. The two other small groups focused on the sustainable aspect and interestingly, their contributions were much more contextualized, including focusing on local impact. The designs included ways to connect to different parts of the city and then later connecting the modes of transportation and cities within the region and beyond to other parts of the country. One of these latter two groups descriptively named their co-designed solution the SolaRide Magic Carpet: an interconnected conveyer system powered by solar power where streets were replaced by moving walkways and benches (see Fig. 6). The other that focused primarily on the sustainability portion created designs for personal electric-solar-powered enhanced bikes and shared carpool vans. An interesting observation from these latter two that focused more on the social imaginary aspects of the design was that both groups included localized maps demonstrating a real focus on local, societal impact.

4.4.2. Reflection on social imaginaries in the co-design process

Children and adults sat on the ground together in a circle and the facilitator discussed the theme for each session at the beginning of the three design sessions that were conducted. In the first session, the focus was on transportation. As such, children and adults discussed various kinds of transportation, the benefits of getting places, and some of the costs including – and particularly – environmental costs. Here children and adults discussed how cars emit gases that can be harmful to the environment as well as the various costs to mine and store fuel sources for vehicles. The facilitator then set the stage for the design work which was to design transportation of the future that would minimize the negative environmental impacts and still provide the benefits of being able to transport people from one place to another. The second session was conducted similarly with a design team a year later that had two prior and five new children members, and a number of new adult members — so the team was significantly different. The last session, focusing on leisure, began with a discussion on long distance travel and the potential impacts on the environment and design solutions to mitigate those challenging impacts. In each session, groups built a shared social imaginary of a future with sustainable travel and leisure — although this social imaginary was less strong in the first session, as multiple groups lacked a focus on sustainability.

4.4.3. Reflections on social imaginaries in designed artifacts

Three design sessions were conducted with children. As noted above, in the first session the collective social imaginary that was built could have been stronger, as only half of the small groups integrated that framing which included sustainability in their designs while the other half focused only on transportation of the future that resulted in more "fantastical" designs such as individual self-driving flying cars and jet-packs. Localized sustainability efforts also manifested in leisure applications, where instead of traveling thousands of miles for vacations, a virtual resort (VResort) could provide an immersive (visual and physical) experience as if you were in that location. Another prototype also capitalized on the virtual and augmented reality space, providing a beach experience where people could pick up trash. If they were in the real world, they would receive points and there would be a leaderboard for those that are providing the most benefit back to the environment (see Fig. 7).

4.5. Case 5: Australia – The growing garbage mountain

4.5.1. The co-design event

The children were presented with a world-wide problem, that of garbage — with the mountain being a visual metaphor they could relate to their everyday experiences. This motivated the children to engage seriously with the topic. The co-design process was facilitated by a researcher with extensive experience in hands-on design workshops. The facilitator, who had worked with one of the school's teachers on earlier projects, planned the workshop content to suit the class's existing curriculum around sustainability. The classroom teacher suggested incorporating the Design Thinking process into the workshop.

The workshop lasted 120 min and took place at a private (non-publicly funded) suburban primary school, involving 30 Year 5 students (ages 9-10) and three classroom teachers. The children were presented with the challenge of designing a "garbage and/or recycling system" to address the issue of "A growing garbage mountain". The children could choose between designing for a home or school environment. The facilitator introduced the children to the Design Thinking process (Hasso Plattner Institute of Design at Stanford University, 2023), which involved the phases of empathizing, defining, ideating, and prototyping. The children worked in groups of 4–5 people, used paper, felt pens,

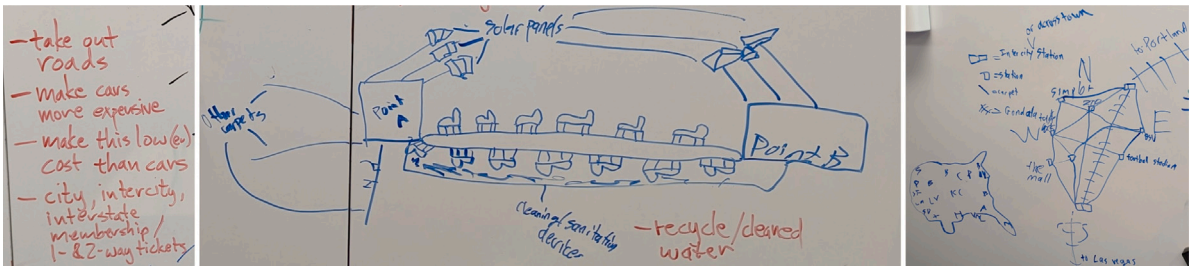

Fig. 6. Case USA. The SolaRide Magic Carpet conveyer of people. This futuristic mode of transportation features conveyer belt-like streets that connect to local, regional, and national locations.

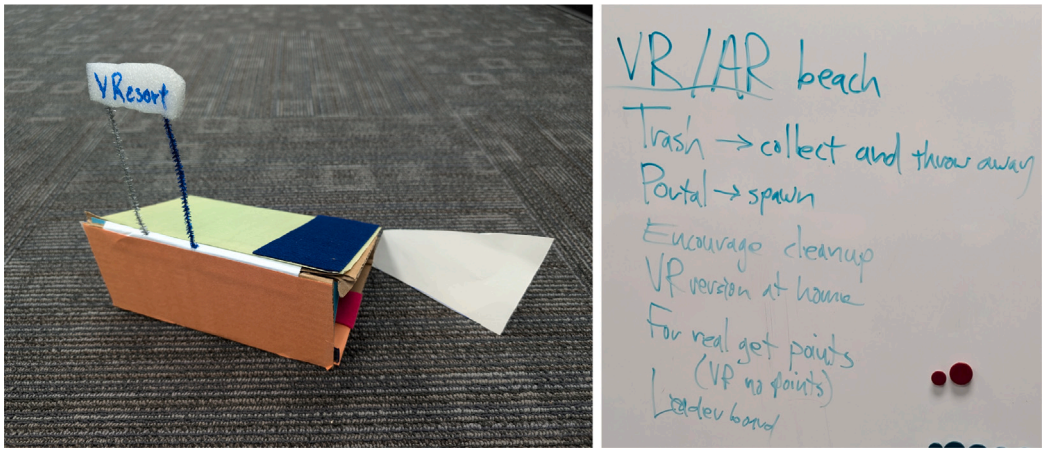

Fig. 7. The VResort is a virtual reality resort was designed separately from the VR/AR beach where people collect and throw away trash.

glue, and scissors to create their designs, and ended the workshop with a presentation of their ideas.

At the end of the workshop, children were asked to complete a short questionnaire similar to the one used in the Romanian study. The children's engagement was monitored by two researchers who made observations during the workshop and took notes. Drawings, writings, and prototypes created during the workshop were also included as part of the documentation.

4.5.2. Reflections on social imaginaries in the co-design process

By framing the design challenge around a growing garbage mountain, the children were encouraged to envision solutions that could address real-world societal issues, building a communal social imaginary that scaffolded the children's understanding of the environmental challenges posed by waste and recycling systems. The use of Design Thinking provided a structured framework that guided the children through empathetic and reflective processes, prompting them to consider the impact of waste and the potential for creative solutions.

Additionally, the idea that children across the globe were also working on similar environmental issues motivated the participants and added a layer of global connectedness to the task. This connection to a larger community of young problem-solvers helped deepen their engagement with the topic, while the opportunity to present their ideas to the class allowed the children to take ownership of their designs and engage in collaborative action.

4.5.3. Reflections on social imaginaries in designed artifacts

The workshop produced various artifacts that captured the children's creative responses to the challenge. These included drawings, paper prototypes, and written descriptions that expressed the children's ideas for waste management and recycling systems, as shown in Fig. 8. Many groups developed designs to make waste disposal more fun and efficient, incorporating elements such as upcycling, recycling, and even financial incentives like selling food scraps for compost. Some groups also focused on educating younger children through their designs, suggesting that the task resonated deeply with their sense of social responsibility and creativity.

The prototypes created by the children were not only tangible representations of their ideas but also visual expressions of their engagement with the problem at hand. The feedback provided by their peers at the end of the workshop highlighted the collaborative nature of the process, reinforcing the value of sharing ideas and learning from others.

In the post-workshop questionnaire, the children expressed high levels of enjoyment and interest in participating in future co-design projects, highlighting the fun and novelty of the design activities. Observations of their behavior and the responses from the children indicated that the workshop was successful in fostering critical thinking, creativity, and a deeper understanding of environmental issues.

5. Discussion

In this section, we first share on overview of the analysis and themes and then provide reflections and recommendations on how to purposefully integrate social imaginaries when co-designing for children.

5.1. Observations from case studies: Themes

The exploration of co-design sessions focusing on environmental challenges through the lens of social imaginaries provided unique insights into children's values, priorities, and imaginative solutions

Fig. 8. Samples of the children's ideation in Australia: (A) brainstorming and (B,C) prototype development of recycling systems.

for the future. Through the different co-design events, children engaged with complex environmental problems and expressed their ideas through drawings, prototypes, and narratives. Their designs often blended fantastical elements with practical solutions, underscoring a balance between imaginative exploration and actionable problem-solving. Reflecting on the events and discussing those reflections, further revealed how children integrated emotional and social values into their solutions, emphasizing the importance of empathy, collaboration, and personal agency in addressing global challenges.

This section describes five common themes that emerged across the case studies with each theme reflecting a unique dimension of children's responses to the environmental crises, informed by their cultural, social, and technological contexts. The themes were developed during whole group meetings in stage three of the analysis (shared reflection) and the examples described here then came from each individual researcher reflecting back on their individual case study (stage four — theme identification)

5.1.1. Emotional connectedness

Research suggests that in order to take things like environmental damage seriously, individuals need to feel emotionally connected to the problem (Restall & Conrad, 2015; Vella, Dema, Soro, & Brereton, 2021). Emotional connection can be seen in designs by considering emotional expressions as well as evidence of empathy with nature.

In Denmark, the children's designs reflect emotional connectedness by imagining underwater villages that build resilience during an environmental crisis. While the facilitator felt the programming objectives were not met, the children's engagement and imaginative immersion in their designs showed a strong emotional awareness of living in harmony with nature. Emotional connectedness appeared as a key theme in Romania, with children emphasizing empathy for animals and nature: "The game may be presented by animals as most of them suffer because of us. They (the animals) could say what we should not do so they don't go through difficulties." The integration of emotional and social values, such as kindness and care for the planet, highlights their vision of a harmonious coexistence with wildlife and the environment. The binary perspective of "good vs. bad" solutions from the UK suggests an emotional commitment to solving environmental problems, with children advocating for tree planting and other eco-friendly practices to "save the world together". This concept of saving the world further demonstrated their social values, often portrayed with multiple people or robots cleaning the planet and improving nature. It may be feasible that the children would then form emotional connections to the technology they would be interacting with Weiss, Wurhofer, and Tscheligi (2009). The emotional connection for children in the USA is less pronounced but can be inferred from groups that focused on sustainability and localized societal impacts, which could stem from a sense of community and responsibility. Children from Australia were inspired by the idea of working on climate challenges alongside peers globally, showing a connection to the broader effort of environmental care. Emotional connectedness emerged through engagement and motivation during co-design sessions.

5.1.2. Social values and binary perspectives

Understanding the nuanced interconnectedness of values and actions is difficult in design (Eriksson, Nilsson, Hansen, & Bekker, 2022; Friedman & Hendry, 2019), and especially for children (Skovbjerg, Bekker, & Barendregt, 2016). Realizing that one impact that appears good in one place, might result in something less good in another, is complex. Research shows that children tend to move away from binary perspectives as they learn more (Bloom, 2002).

Binary perspectives were explicitly noted in the UK, as children categorized actions and technologies as either "good" (e.g., robots and tree planting) or "bad" (e.g., littering). This clear dichotomy framed their designs and ideas for environmental action. In the USA, children showed nuanced thinking rather than binary perspectives, balancing local impacts with broader goals. Similarly, binary perspectives were less evident in the studies in Denmark, Romania and Australia. The children's focus in Denmark on resilience during environmental crises implies an optimistic, constructive view of overcoming challenges rather than a strict binary good and bad perspective but we should note that these were older than many others in the case studies. Romanian children emphasized kindness and positive values, suggesting a rejection of binary thinking in favor of inclusive and collaborative solutions. Children in Australia explored a range of creative solutions that would improve local waste and recycling management, and directly improve the children's environment rather than categorizing ideas into good or bad.

5.1.3. Connectedness and shared goals: Local to global impact

As Thomashow (2001) writes, one can think locally and act globally or think globally and act locally — both are good solutions for climate change and environmental sustainability. Other researchers have highlighted the importance of making the connection between local action and global consequences (Vella et al., 2021) and have advocated for distributed, boundary-crossing learning, and sharing of global involvement (Winschiers-Theophilus, Goagoses, Rötkönen, & Zaman, 2022b). With mentions of playing with others worldwide or cleaning the whole planet, the children's prototypes reflect an imaginary of global interconnectedness. They see environmental challenges as universal, requiring cooperation and understanding that includes local and global actions.

The underwater village designs in Denmark highlight local resilience but lacked explicit references to global interconnectedness. Romanian children demonstrated a strong sense of global interconnectedness, envisioning actions that span the entire planet, such as cleaning garbage worldwide: "In each level you need to collect garbage from all over the world." They expressed optimism about collective action leading to large-scale impact. In the UK, the designs reflected collective action through tree planting and recycling, with a strong emphasis on community efforts to save the local environment. The focus on sustainable transportation systems in the USA showed a mix of local and regional impacts, with some designs addressing connections between cities and the country as a whole. Global collaboration was a source of motivation for children in Australia and also from Romania. Knowing that their work was part of a global initiative illustrated a sense of connectedness to a worldwide effort to address climate challenges.

5.1.4. Blended experience: Blending reality with digital interactions

By envisioning activities that require going outdoors or interacting with real environments, the children illustrate a social imaginary that blurs the line between digital and physical worlds. They imagine technology as a facilitator for real-life actions, reflecting a belief in the value of engaging with the environment directly. This aligns with arguments that, to the children of today, nature and technology are in direct competition (sometimes described as the nature-technology binary) and that this notion is indeed a false dichotomy (Kumpulainen, 2022). Instead, our research aligns with other work that support that technology can facilitate engagement with nature, and nature play can support computational thinking (Om et al., 2024).

In Denmark, the prototypes blurred reality and imagination by, for example, creating a digitally enhanced world of underwater villages in which TVs and sea creatures coexisted. Blended experiences were explicitly imagined in the study in Romania, where children envisioned games that required players to go outdoors and interact with real environments, such as a Pokémon GO-style app: "Similar meaning people need to go outside in order to play the game." This illustrates the merging of digital play with physical environmental action. While blended experiences were not directly highlighted in the UK, USA and Australian studies, the UK children's use of technology, such as robots, to address environmental problems suggests some integration of digital and physical solutions; in a similar way, in the USA, the fantastical designs of flying cars and solar-powered transportation systems could imply a digital enhancement of real-world mobility. Conversely, in Australia, children focused on real-world solutions including technology as part of the solutions: their prototypes emphasized practical, tangible designs as well as digital interactions.

5.1.5. Empowerment

Empowerment is a cornerstone in participatory design (Bødker et al., 2022), and in PD with children (Van Mechelen, Have Musaeus, Iversen, Dindler, & Hjorth, 2021; Iivari & Kinnula, 2018; Wilson, Atabey, & Revans, 2025). The idea that small actions in a game (like recycling or cleaning) lead to large achievements, such as becoming a president, indicates a belief in the power of individual contributions to create significant, positive change. This shows an underlying optimism in personal agency within a shared global responsibility. Children see environmental responsibility as an ongoing journey, where individual contributions lead to significant change and recognition.

Children in Denmark demonstrated empowerment by creating their own designs and imagining solutions to environmental challenges, even if the practicalities were secondary. Empowerment was a central theme in Romania, with children envisioning individual actions (e.g., recycling) leading to significant achievements like "becoming a president" or making global impacts. Their focus on creativity and personalization further reinforced feelings of agency and control: "Children should be able to create new things, worlds, characters. We (children) should be able to create our own world in which we would like to live." In the UK case, while children generally appeared empowered, some were limited by their ability to get started in a design; several children expressed a wish to enact their ideas as they left the classroom. Empowerment was evident in the USA case, through the localized, community-driven solutions, particularly in the designs for sustainable transportation systems that prioritized societal needs and high levels of engagement. Creative freedom, and teamwork fostered empowerment among the children in Australia. They expressed pride in their ability to work as designers and scientists, and to contribute to environmental solutions.

5.2. Social imaginaries and PD

In Schön's description (Schon, 1984), reflection has both a crucial importance for helping the expert (here the PD facilitator) to orient and make sense of the unique situation they are facing; and is the method through which the experts develop their competence. As such, a PD facilitators' expertise relies on patterns that they can, consciously or unconsciously, draw on and appropriate within the novel situation; and these patterns are learned through earlier reflection-in-action (Schon, 1984; Slovák et al., 2017). This reflective practice was evident in the Denmark case study, where the facilitator strategically used an engaging visual cue – the flooding of the children's village – to prompt children to construct their own understanding of climate change impacts rather than imposing information on them. This approach allowed children to actively shape the social imaginary and engage deeply in the design process when setting the scene.

Similarly, balancing the 'real-but-not-too-real' (Slovák et al., 2017) aspect of experiences played a key role in scaffolding children's social imaginaries of environmental sustainability. The challenge is to make abstract concepts relevant without overwhelming children with the magnitude of environmental crises. In Denmark, sea-level rise became tangible to children when they envisioned their village submerged, yet it remained within a conceptual 'safe space' that encouraged exploration rather than fear. The children developed a shared social imaginary of environmental sustainability, and they could take action at that level, but they never really started to reflect and question it. So this remains an unexplored issue: how to scaffold children's social imaginaries of environmental sustainability so that they move from taking action to starting to ask the important questions for real change? Therefore this is a limitation that needs further investigation.

In Romania, by scaffolding reflection and providing space for imaginative co-design, the project helped children envision a collaborative, empathy-driven world where individual actions contribute to broader environmental goals. This integration not only enhanced children's understanding and engagement with sustainability but also empowered them to imagine, and participate in, a socially responsible future.

In the UK, the children developed shared social imaginaries that motivated them to engage with the 'big picture', to "save the world together", at the expense of the session focus of re-use. In contrast, in Australia, 'Garbage Mountain' became the basis for a shared social imaginary that enabled children to design local solutions, motivated by a real-world, global problem. This shows that emergent social imaginaries can impact children's motivation and focus in participatory design. Intentionally leveraging the act of building social imaginaries together could be used in future participatory design research to better scaffold design activities and help the children to focus on specific topics.

In the US, we found that some but not all groups reflected on sustainability in a local-to-global context. Those groups generated their own shared social imaginaries that informed their (relatively) grounded designs. In contrast, groups that did not build social imaginaries that focused on sustainability designed more "fantastical", individually-focused means of transportation. This suggests that intentional use of social imaginaries could support children in creating more grounded designs for big problems.

The application of social imaginaries in co-design shows promise in empowering children to bridge the gap between abstract, global challenges and their immediate, tangible experiences, fostering a sense of agency and relevance. By encouraging children to envision how large-scale issues like climate change or sustainability manifest in their local contexts, such as pollution in their neighborhood or waste management in their schools, social imaginaries help translate abstract concepts into relatable, actionable ideas. This localized approach not only enhances children's understanding but also inspires them to see themselves as capable change agents who can contribute meaningful solutions within their communities.

More importantly, our findings suggest that social imaginaries do not merely support engagement, they actively shape the quality and focus of children's design work. When facilitators scaffold experiences around emotionally resonant and culturally grounded imaginaries, children are more likely to produce grounded, imaginative, and socially cohesive artifacts. This shows the transformative potential of using

social imaginaries not just as an analytical lens, but as a deliberate design strategy in participatory design.

Therefore, we advocate for future co-design initiatives to intentionally adopt social imaginaries as a foundational framework, particularly when addressing complex societal challenges such as environmental sustainability. Social imaginaries provide more than just thematic inspiration; they offer a powerful scaffolding mechanism for co-design processes by anchoring abstract global issues in culturally meaningful and emotionally resonant contexts. When integrated thoughtfully, this approach enables a more holistic and impactful engagement with participants, especially children. This approach further resonates with the importance of designing child-centered, participatory technologies that foster environmental awareness, critical thinking, and action, while acknowledging the emotional and cognitive challenges children may face in confronting the climate crisis (Vasalou & Gauthier, 2023).

Based on our experience, we believe that purposefully leveraging social imaginaries can:

- **Strengthen emotional connection and collective motivation** by creating narratives that resonate personally and socially, encouraging deeper engagement with design challenges.
- **Ground fantastical ideas in local relevance**, helping participants connect visionary thinking with tangible realities and community needs.
- **Enhance facilitators' capacity to scaffold reflection and creativity**, providing structure to balance imaginative exploration with critical thinking and social responsibility.
- **Foster the development of shared visions of change**, allowing diverse participants to work together around common values, hopes, and goals, thus enhancing collaboration and inclusion.

By embedding social imaginaries into participatory design, the process evolves from a method of idea generation to a transformative practice of future making. This shift enables designers and participants to co-create meaningful, context-sensitive solutions that are grounded in lived experience and oriented towards sustainable, socially impactful change.

6. Conclusion

The analysis of children's participatory design sessions across five countries highlights the profound potential of combining social imaginaries with co-design to address environmental challenges. By exploring complex societal issues through imaginative and collaborative activities, children were able to localize abstract global problems and propose innovative solutions that blended emotional connectedness, social values, and actionable goals. Themes such as emotional awareness, the interplay of local and global impacts, and the blending of digital and real-world experiences emerged, underscoring the diverse ways in which children envision their role in creating sustainable futures. Children also demonstrated a strong sense of agency and empowerment, evident in their creative designs and proactive solutions. Whether imagining underwater villages in Denmark, proposing global clean-up initiatives in Romania, or designing sustainable transportation systems in the USA, their ideas reflected a balance of optimism, collaboration, and critical thinking. Emotional and social values such as empathy, community action, and responsibility were central to their designs, reinforcing their belief in the power of collective action to address environmental issues.

Our initial purpose was to co-design sustainable solutions with children. We did not intentionally use social imaginaries; but when analyzing our results using social imaginaries as a lens, we realized that children were building off the contextualizing information we provided, to construct their own social imaginaries. The children's designs embody their social imaginaries, allowing us to understand how they have understood and engaged with the participatory design tasks we set before them. When the children's emergent social imaginaries aligned with the goals of the participatory design sessions, the co-designed artifacts were more situated and realistic. As such, we encourage co-designers to intentionally and purposefully use a social imaginary framework when designing technologies for societal impact. The development of impactful sustainable solutions, particularly those designed with and by children, demands a paradigm that extends beyond conventional design approaches. By intentionally and purposefully integrating social imaginaries into co-design processes, we open pathways to a deeper, more transformative engagement with the diverse perspectives, aspirations, and lived realities of all stakeholders. Social imaginaries invite us to envision not only what is but what could be, fostering innovation that is empathetic, inclusive, and grounded in shared values.

The primary contribution of this paper is an illustration of the use of social imaginaries for interpreting and organizing co-design around environmental sustainability. Our findings underscore the importance of integrating social imaginaries more intentionally into co-design practices. By fostering emotional engagement, providing contextual relevance, and empowering children as change agents, co-design can inspire meaningful contributions to global challenges. This approach not only nurtures creativity and agency in young participants but also offers valuable insights into the imaginative and actionable solutions they envision for a sustainable future.

7. Selection and participation of children

No personal data was gathered from individual users throughout the co-design sessions from each of the five sites. Local ethics approvals were obtained by each of the five international research teams. In most cases (Denmark, Romania, UK, Australia), students were recruited through existing collaborations with the university and local schools. In USA, the children are part of a pre-existing intergenerational design team. Adult consent and child assent were obtained prior to conducting all co-design sessions.

CRediT authorship contribution statement

Jerry Fails: Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Aurora Constantin:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Eva Eriksson:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Janet Read:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Gavin Sim:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Marie Boden:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jessica Korte:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Sanjana Bhatnagar:** Writing – review & editing, Investigation, Data curation. **Judith Good:** Writing – review & editing, Validation, Methodology, Investigation.

Declaration of competing interest

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

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Data availability

Data will be made available on request.

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