Inclusion as a Process: Co-Designing an Inclusive Robotic Game with Neurodiverse Classrooms

Patricia Piedade
Interactive Technologies Institute,
University of Lisbon
Lisbon, Portugal
patricia.piedade@tecnico.ulisboa.pt

Isabel Neto
INESC-ID, University of Lisbon
Lisbon, Portugal
isabel.neto@tecnico.ulisboa.pt

Ana Pires
Interactive Technologies Institute,
University of Lisbon
Lisbon, Portugal
ana.pires@iti.larsys.pt

Rui Prada
INESC-ID, University of Lisbon
Lisbon, Portugal
rui.prada@tecnico.ulisboa.pt

Hugo Nicolau
Interactive Technologies Institute,
University of Lisbon
Lisbon, Portugal
hugo.nicolau@tecnico.ulisboa.pt

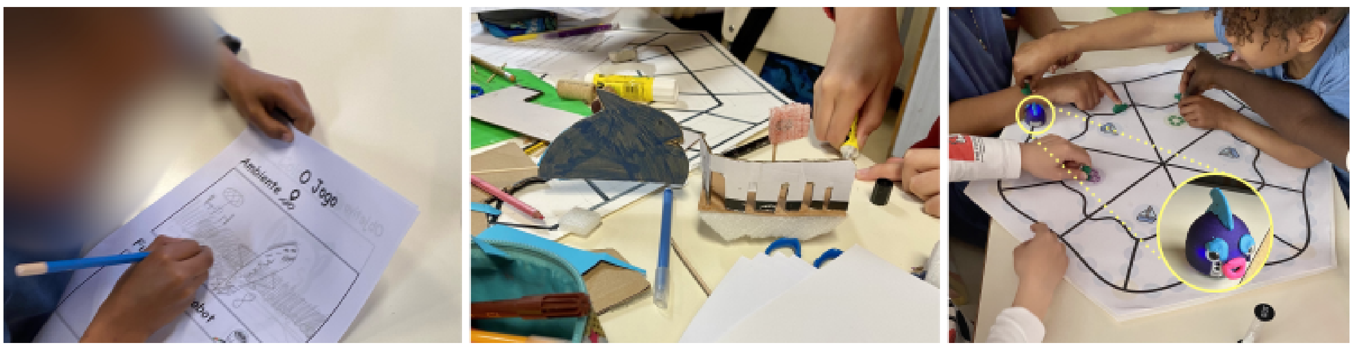

Figure 1: Stages of the co-design process of a robotic game with neurodiverse children. Left: Child filling out a worksheet detailing their group's game elements. Middle: Neurodiverse group of children creating a low-fidelity prototype of their game. Right: Neurodiverse group of children playtesting the high-fidelity prototype of the game they co-designed.

ABSTRACT

Neurodivergent children spend most of their time in neurodiverse schools alongside their neurotypical peers and often face social exclusion. Inclusive play activities are a strong vehicle of inclusion. Unfortunately, games designed for the specific needs of neurodiverse groups are scarce. Given the potential of robots to support play, we led a co-design process to build an inclusive robotic game for neurodiverse classrooms. We conducted five co-design workshops, engaging 80 children from neurodiverse classrooms in designing an inclusive game. Employing the resulting design insights, we iteratively prototyped and playtested a tabletop robotic game leveraging off-the-shelf robots. Reflecting upon our findings, we discuss how the longitudinal co-design process (rather than the resulting game) was key in allowing children the space to learn how to accommodate accessibility needs and create inclusive play experiences. We posit the use of co-design to enhance children's interpersonal relationships, foster feelings of ownership, and encourage appropriation practices as a strategy to sustain inclusive experiences that extend beyond project timelines or artefact designs.

CCS CONCEPTS

• Social and professional topics → Children; **People with disabilities**; **• Human-centered computing → Empirical studies in HCI**; **• Applied computing → Education**.

KEYWORDS

Co-design, Classrooms, Children, Neurodivergent, Inclusion, Games, Neurodiverse

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1 INTRODUCTION

Play is a powerful activity to promote children's development [34, 59]. Research shows how play supports the development of intelligence, creativity, social skills, and perceptual abilities [17, 18, 20, 27]. While playing, children develop friendships, learn to negotiate and cooperate, and develop communication skills [19, 22]. Beyond the developmental benefits, play is a source of joy and fun, allowing children space for self-expression and exploration [19, 29]. Indeed, play is recognised in the United Nations Convention on the Rights of the Child as a fundamental human right [56]. Games are widely used to unlock the benefits of play, offering pleasurable engagement and positive outcomes for players' well-being [28, 30]. Moreover, they have the potential to promote inclusive experiences and equally engaging experiences for players with and without disabilities [38].

However, neurodivergent players still face reduced opportunities for inclusive play experiences and access to their associated benefits. Throughout this paper, we use the concept of *neurodiversity* to address the multitude of neurological differences in human brains, which operate within the identity model of disability [47, 50]. We acknowledge neurological differences as an expression of the variety of human brains where most brains are *neurotypical*, and some diverge from these norms, thus, referred to as *neurodivergent* (e.g., Attention Deficit Disorder (ADHD), Autism, Dyslexia, and Intellectual Disabilities) [11].

In a recent critical review of games and playful systems developed by the HCI research community specifically targeting neurodivergent players [54], Spiel and Gerling show that games are primarily designed for medical and training purposes (i.e., serious games). The main goal of these games is to dress up boring and repetitive activities, which tend to prioritise training over play and are driven by factors extrinsic to neurodivergent interests. Moreover, games are designed with a top-down approach and intended to be used by neurodivergent players alone, reducing opportunities for social interaction and inclusive experiences.

This paper investigates how to facilitate inclusive play experiences for neurodiverse children, i.e., groups composed of neurodivergent and neurotypical children. Drawing inspiration from the work of Metatla et al. [38], we explore the potential of small robotic devices to design inclusive games through a seven-month design process with 80 neurodiverse children (18 neurodivergent) from a mainstream school. Robotic devices are endowed with a physical presence, provide multimodal feedback, and can operate within a spectrum of autonomy (from human-controlled to fully autonomous). Although robots have shown to be highly engaging to children and a relevant tool for facilitating teamwork [2, 3, 38, 41–43, 46, 48], their potential remains largely untapped for inclusive games, particularly when considering neurodiverse groups of children [54].

We aim to answer two main research questions: (1) how do inclusive co-design activities within neurodiverse classrooms influence the dynamics of neurodiverse groups of children and the co-design process? (2) how does the resulting game support inclusive play for both neurodivergent and neurotypical children? To answer these questions, we took on a Research through Design approach [58], leveraging the design process to better understand group dynamics in neurodiverse groups of children. We ran 5 co-design workshops with four neurodivergent classrooms to create an inclusive game using Ozobots [1] (Fig. 1), from which we derived a set of design insights. For the final stage of the design process, we designed and prototyped a robotic game based on these design insights. We then conducted a workshop with game design students to refine the prototype. Finally, we evaluated it in neurodiverse classrooms, including one that was not part of the co-design process.

Our findings highlight the profound impact of co-design on fostering inclusive play. The inclusivity within the evaluation workshop was remarkable as co-designers actively engaged and celebrated together, even within competitive aspects of the game. However, it was not simply the co-designed artefact that promoted inclusion but the collaborative co-creation process. Co-designing a game and witnessing its materialisation fomented a sense of ownership and connection, which fostered greater tolerance towards each other's actions, empowering them to assume authority within the game and seamlessly appropriate and adapt rules without conflict.

We contribute a demonstration of how conducting co-design processes with neurodiverse groups as classroom activities can lead to the creation of novel inclusive games. Furthermore, they lay the groundwork for designing inclusive gaming systems tailored to the needs of neurodiverse groups of children. Moreover, they shed light on the positive impact on tolerance and inclusiveness stemming from involving neurodiverse classrooms in the co-design process.

2 RELATED WORK

In this section, we review previous work on games designed for neurodivergent players and neurodiverse groups, co-design methodologies aimed at neurodiverse groups, and the use of robots by neurodivergent individuals. We highlight the scarcity of research on robotic games for neurodiverse groups.

2.1 Games for Neurodivergent Players

Most research focuses on a single diagnosis, mainly autism, and single-player games [54]. On the other hand, multi-player games tend to focus solely on neurodivergent groups [51]. Notably, most games fail to take a participatory approach and focus on developing serious games with educational or therapeutic goals [54]. Games research has explored many diagnoses under the neurodivergent umbrella alongside various gameplay mechanics and goals, for example, an exergame for people with intellectual disabilities [55], a cooperative virtual tabletop game for the development of social skills among neurodivergent teens [45], a networked videogame to enhance social play among children with cerebral palsy [57], a therapeutic game for children with autism [26], a calming biofeedback game for children with ADHD [53], a set of videogames for dyslexia diagnosis [5], or co-created games as a learning tool for students with learning difficulties [37]. Our work aims to co-design a game with group engagement and enjoyment as its primary goals alongside inclusion.

2.2 Games for Neurodiverse Groups

This section highlights examples of games created for neurodiverse groups, including neurodivergent and neurotypical players. Through co-design approaches, games have been created to explore

[1] https://ozobot.com

	Class 1 (4th grade)	**Class 2** (4th grade)	**Class 3** (2nd grade)	**Class 4** (2nd grade)
Age	9-12, M=9.52, SD=0.81	8-10, M=8.94, SD=0.43	6-8, M=7.05, SD=0.59	7-11, M=7.55, SD=1.01
Gender	13 girls and 8 boys	11 girls and 6 boys	8 girls and 13 boys	11 girls and 11 boys
Groups	G01, G02, G03, G04	G05, G06, G07, G08	G09, G10, G11, G12	G13, G14, G15, G16
Neurodivergent	G01ND3 - LD G02ND1 - LD G02ND6 - LD G03ND3 - LD G03ND4 - LD and Dyslexia	G05ND1 - ID G05ND4 - ID G06ND2 - ADHD G06ND3 - ADHD G06ND1 - LD	G10ND5 - LD G11ND3 - LD G12ND1 - LD G12ND3 - LD	G13ND1 - GDD G15ND2 - LD G16ND1 - LD G16ND6 - LD

Table 1: Demographics of the classes participating in the co-design process. LD: Learning Differences, ID: Intelectual Disability, GDD: Global Developmental Delay, ADHD: Attention Deficit and Hyperactivity Disorder

the potential for social play among neurodiverse groups [1, 15]. Researchers have used games to engage neurodiverse groups in social and emotional learning [52] or even teach them about archaeology [36]. Tangible technologies are frequently the basis of these games [1, 15, 36]. However, other approaches, such as tablet interfaces [52], and AR [9], have also achieved inclusive results. Neurodiverse groups are less often the focus of game research [51, 54]. However, mixed-ability gaming scenarios have proved effective in promoting inclusion and equity among players with varying disabilities [14, 44], with and without motor impairments [21, 24] or with and without visual impairment [38, 46, 48]. In this work, we aim to create a tangible game that leverages the potential of robots as an inclusion facilitator in neurodiverse groups of children.

2.3 Neurodivergence and Robots

Games designed for neurodivergent players rarely include robots [54]. However, robots proved effective in eliciting prosocial behaviours from neurodivergent children in both at-home [31] and in-school [33] scenarios. Educators recognise the potential of utilising robots in neurodiverse classrooms [6], and these have proved effective in teaching computational thinking skills to neurodivergent students [32]. In one of the few gameplay scenarios, neurodivergent adults reacted positively to a robot as a game element [4]. Building upon the positive impact of social robots on neurodivergent individuals and robots' potential for inclusion in mixed-ability scenarios [38], we aim to co-create a robotic game with neurodiverse groups.

2.4 Co-Designing with Neurodiverse Groups of Children

Including children in the design process of technology aimed at them is essential to ensure their voices are heard, and their needs and preferences are considered during the design process [13]. Researchers developed techniques, such as Expanded Proxy Design [39] and Cooperative Inquiry [25], caregivers interviews [40] to promote the inclusion of children with disabilities in the co-design process. When engaging such children in co-design, one should consider providing support for writing activities [25], creating a balance between structure and freedom [35], and promoting multisensory crafting activities [38]. Diversity for Design [7] and Agnostic Participatory Design [15, 16] were specifically formulated towards the inclusion of neurodivergent children, highlighting the importance of understanding neurodivergent culture but tailoring activities to the specific individuals [7], viewing disagreement from a constructive lense [15, 16] and focusing on interpersonal relations rather than group dynamics [40]. Our work combines these methodologies to create a co-design process that is accessible and equitable for neurodiverse groups.

3 DESIGN PROCESS

Aiming to create an inclusive game for neurodiverse groups of children, we took on a seven-month-long design process involving multiple stakeholders, from the children themselves to their teachers and game design students. This was done in three main phases, in-the-wild **co-design workshops**, which provided insights for the **iterative game prototyping**, whose prototype we tested in the **game evaluation**. In the next sections, we describe in detail each of the three phases of the design process. Throughout this process, we identify multiple design insights, from hereon referred to as **DIn**, that informed the conceptualization and creation of our final game prototype. Moreover, observational insights are thematically grouped and numbered as **[O<x>]**, for ease of referencing. The themes are as follows: **[O1]** Engagement and Disengagement; **[O2]** Group Dynamics; **[O3]** Activity-specific Interactions; **[O4]** Emotional Reactions; **[O5]** Neurodivergent-specific Observations; and **[O6]** Control-group-specific Observations. The taxonomy of these thematic groupings is included as supplementary material, which we hope may aid others in analysing observational data from in-the-wild classroom co-design activities. We obtained written informed consent from all adult participants and from the legal guardians of child participants, as well as spoken assent from the children. This project received approval from our institution's Ethical Review Board.

3.1 Co-Design Workshops

We ran co-design workshops with neurodiverse classrooms, designing an inclusive robotic game and exploring the research question: *How do inclusive co-design activities within neurodiverse classrooms influence the dynamics of neurodiverse groups of children and the co-design process?*

3.1.1 Setting and Participants. We worked with four neurodiverse classrooms in a local public school: two second grades and two fourth grades. In this school, all neurodivergent students are integrated into mainstream classrooms, receiving support from inclusive education teachers when necessary. Teachers noted that group

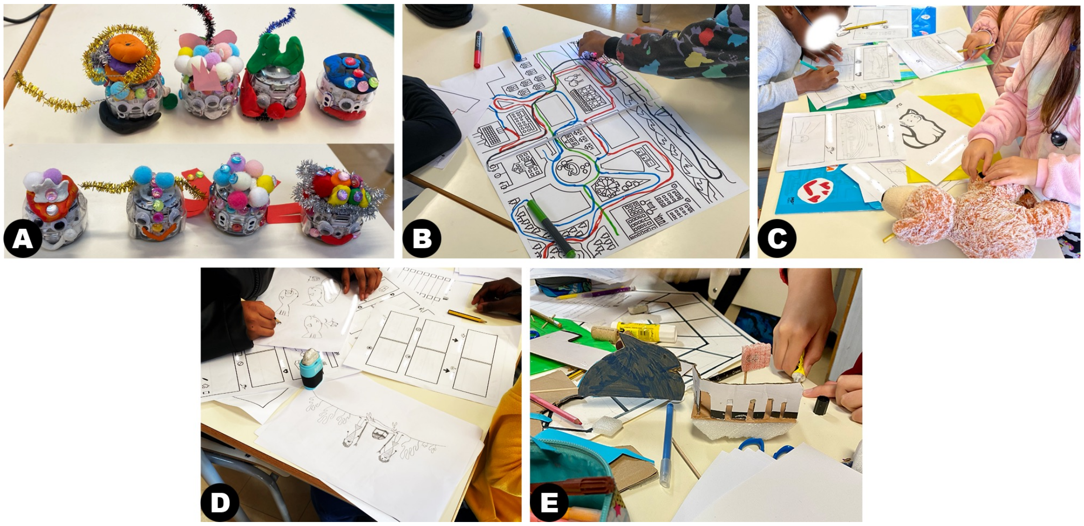

Figure 2: Co-Design Workshops. (A) Customised Ozobot from Workshop 1. (B) Map activity from Workshop 2. (C) Expanded Proxy Design from Workshop 3. (D) Game conceptualization from Workshop 4. (E) Prototype from Workshop 5.

work and games are relevant and engaging parts of their teaching strategy. The school is located in the suburbs of a major Western European city, within a low socioeconomic neighbourhood, and serves a multicultural school population, including migrants.

From hereon, each child will be denoted as *G<x><n><i>* (x-group number, n-NT for neurotypical or ND for neurodivergent, i-within-group identifier). Overall, 80 students [2] (43 girls and 38 boys, 6-12 years M=8.22 SD=1.26) participated in the co-design sessions. Eighteen children were identified as neurodivergent; 13 had Learning Differences (1 also had Dyslexia), two had Intellectual Disabilities, two had ADHD, and one had Global Developmental Delay (Table 1).

Each teacher divided their class into four groups of 4 to 6 children based on children's interests, friendships, and usual seating arrangement. However, G15ND5, a child with Down's Syndrome, was removed from the project during the first workshop, as his teacher claimed he was too overwhelmed by the activities.

3.1.2 Procedure. The co-design process consisted of five 1h30m sessions. The workshops leveraged off-the-shelf child-friendly Ozobot Evo [3] robots, which have proven effective in both mixed-ability co-design [38] and neurodivergent education [32] scenarios. The Ozobot is a small (2.5cm diameter x 2.5cm high) robot with two wheels, a colour sensor, speaker, and colour-changing LEDs. It can follow lines drawn on a surface, interpret colour codes within them to perform specific behaviours, and be piloted through a remote control app.

The class's teacher and two to three researchers were present for each session, introducing and setting up activities while observing and facilitating group work. Workshops gradually introduced children to both the robots and game design fundamentals, allowing them to make choices regarding the game's design (Fig.2).

[2]Detailed information per child is available in supplementary materials.
[3]https://shop.ozobot.com/products/evo-entry-kit-1

We employed the PartiPlay Game Design Kit [45], a methodological kit crafted for neurodiverse classrooms. Each child kept a project portfolio to store worksheets and other materials created throughout the process, inspired by Malinverni et al. [35]. All worksheets included pictograms, text, and enough space to write or draw answers, supporting children who struggled with reading and writing.

The research team video-recorded all co-design sessions, and the lead researcher wrote field notes, discussing them with other researchers at the workshops. We analysed the 160 hours of footage, using a 10k-word document of field notes as a guide, locating noteworthy moments in the videos and analysing them further. We used a deductive coding approach and created affinity diagrams based on collected data from each session. Two researchers iterated on the codes and categorisation of the data, which were then discussed and refined with the entire team.

3.1.3 Workshop 1: Building Rapport. The goal of the first workshop was to familiarise the children with the technology and methodology that would be used throughout the project and get them acclimated with their fellow group mates and the research team. We aimed for children to explore the robot and establish in-group collaboration. For this effect, we started with a round of introductions, followed by each child customising their portfolio folder, and then each group decorating an Ozobot and presenting it to the class (Fig.2A). It is noteworthy that while the portfolio customisation task was individual, decorating the Ozobot required group work.

Observations: All participants showed enthusiasm after seeing the Ozobot for the first time, huddling together to get a better look **[O1.1]**. **DIn1: Children are easily and consistently engaged by the Ozobots.**

Though all groups successfully decorated their robot, their takes on collaborative work and resulting tensions differed. In some groups, more dominant elements took over decision-making, requiring researcher intervention to promote equal participation **[O2.1]**.

For instance, G01NT2, the oldest among his group, directed G01ND3 on how to decorate the robot, while the remaining group members, were excluded from the task until researchers encouraged them to join in. Similarly, G015NT5 and G015NT3 initially took over decorating; after hearing complaints from the group, the teacher implemented a turn-taking mechanic where each child added one decoration on their turn. Still, G15ND2 struggled to assert his turn. In others, members got stuck arguing between two different options but reached a compromise with gentle nudging from the researchers **[O2.2]**. When choosing a colour for their Ozobot's clothing, G13NT2 and G13ND1 wanted red, while G13NT4 wanted green. They kept verbalising these opposing views until a researcher suggested a compromise by using red and green. When prompted to name their robot, G14NT1, G14NT2 and G14NT4 were set on the feminine "Lily", and G14NT3 preferred the masculine "Elias". The group ended up agreeing on a merge suggested by a researcher "Lily Elias". A few avoided the conflict altogether **[O2.3]**. For example, in group 12 (neurodiverse), each group member created their own "robot" out of the decoration materials while passing around the Ozobot and adding a decoration in turn. Group 2 collaborated effectively, easily reaching agreement on most decisions. Though G02ND6 repeatedly interrupted groupmates and took decorating materials out of place, they were seemingly unbothered. G02NT4 shared with the researchers they were used to this behaviour and knew to ignore it.

3.1.4 Workshop 2: Exploring the Ozobots. The second workshop explored the possible behaviours and means of control of the Ozobots. We crafted three playful group activities for this effect: a storytelling activity where students used the markers to take the Ozobot through its day on a map (Fig.2B); a problem-solving game where they built a path with puzzle pieces to drive the Ozobot home; and a creative activity where they used the remote control to make the Ozobot dance to a song of their choosing.

Observations: When researchers turned on the robots and placed them on the group's tables, their enthusiasm was clearly visible, with several students leaning over in their seats to get a better look and even clapping **[O1.1]**. Despite several clarification attempts by the research team, all groups struggled to control the Ozobot using colour codes, finding alternative ways to cope with the problem-solving activity: group 8 used their hands to guide the robot along the intended path; group 10 built a linear path, while group 1 completed the activity on the first attempt by sheer luck. **DIn2: Children find Ozobot's colour codes overly complicated.**

On the other hand, all groups easily grasped the remote control feature. Even using it outside the intended activity, like G05ND1, who drove the robot through the classroom floor. **DIn3: The remote control app is the student's preferred way of interacting with the robot.**

Students employed different collaborative strategies depending on their group and the activity **[O2.3]**. In group 5, G05ND1 took the lead during the dancing activity, while G05ND4 took responsibility for drawing on the map. The difference in activities allowed them both to take initiative while listening to group input. Group 4 shared control of the robot alternating in one-minute intervals based on G04NT4's wristwatch. In contrast, G01NT2 and G01ND3 shared the task, the first controlled movement, and the second the LEDs (Fig.3A). **DIn4: Alternating between activities that vary in format and required skills promotes high engagement.**

Some groups started to grasp the idea of reaching compromises **[O2.2]**. For example, G02ND6 disagreed with his group's song choice but wound up suggesting a singer, leading G02NT3 to choose a song by that artist everyone liked. While many still required more active moderation **[O2.4]**. For instance, group 16 struggled with resource sharing, with each member yelling for what they wanted and G16ND1 feeling unheard. The presence of a researcher promoting turn-taking and encouraging participation mediated the issue.

3.1.5 Workshop 3: Expanded Proxy Design. This workshop aimed to introduce children to the building blocks of inclusive game design. First, children participated in a warm-up activity where they shared their favourite games, which we used to demonstrate how to fill out the workshop's worksheet detailing game elements (Fig.2C). In an Expanded Proxy Design [39] activity, children created and presented to the class a game that was themed after Sustainability and Oceans[4] and used Ozobots to play with a new stuffed animal friend with neurodivergent characteristics (e.g., Maribel the Giraffe, who is social, creative and struggles with reading and writing).

Observations: When sharing their favourite games, most children mentioned playground games such as catch, hide and seek, and soccer, as well as online games like Minecraft or Roblox. **DIn5: Children prefer playground games, sports and video games, all of which are competitive.**

Children were incredibly receptive to the proxies, screaming in excitement upon seeing them and hugging them tenderly throughout the workshop (Fig.3B) **[O3.1]**. Two neurodivergent students verbally made the connection between themselves and the proxy. For example, G05ND1 said, *"She is like me! [...] She may not be able to read and write, but she has a good heart."*. Children kept the proxies' characteristics in mind, recalling them throughout game design and incorporating them into their game concepts. G10NT2 kept reminding the group of their proxy's difficulties focusing, eventually suggesting that the Ozobot should call its attention when distracted. Because G02ND6 thought their proxy's disruptive nature was a positive attribute, the group created a game concept that allowed it to use pranks against in-game enemies. The accessible worksheets and the researcher's encouragement towards using drawings to express ideas, if children preferred, posed as a relief for students who were not native speakers and for neurodivergent students who struggled with writing **[O3.2]**. For example, G03ND4 became distressed from being unable to write as fast as her groupmates but was overjoyed when researchers suggested she draw instead, showcasing her sketches with pride. We found that neurodivergent students tended to be very attached to their ideas, leading groups to find creative ways to incorporate these **[O5.2]**. In one case, G06ND2 wanted the game to be based on hopscotch, while the remainder of the group preferred hide-and-seek. G06ND2 refused to conform, and the final game had the player play hopscotch while the robot hid away.

[4]Teachers identified Sustainability and Oceans as a cross-disciplinary curricular theme common to all grade levels, which should be incorporated in the project.

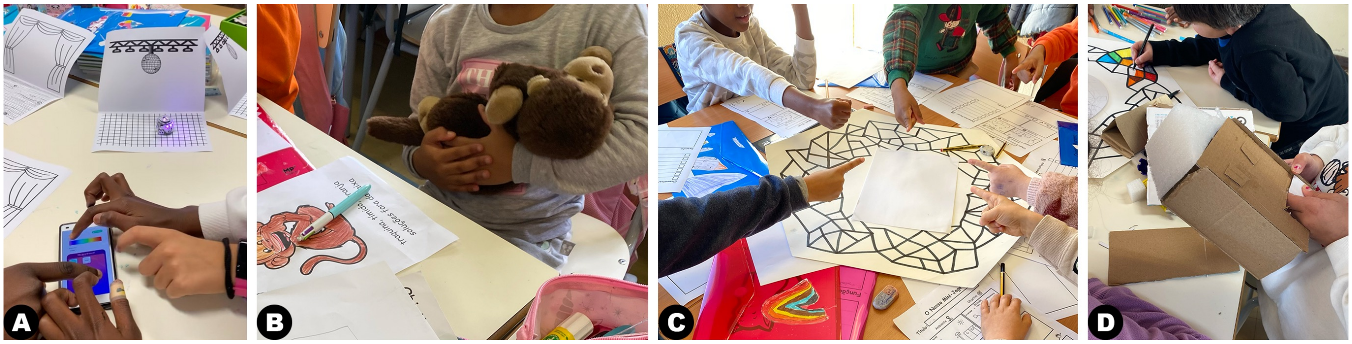

Figure 3: Interactions and Groupwork during Co-Design. (A) Collaboration in the dance activity from Workshop 2. (B) Affection towards a proxy from Workshop 3. (C) Handshake game for decision-making in Workshop 5. (D) Task distribution in Workshop 5.

Analysis of Narratives: Two researchers analysed pictures from the children's worksheets and recordings of their presentations, identifying common elements in the game concepts through an inductive coding approach.

From the 16 game concepts, we identified catch as the predominant game mechanic (10/16). Concepts revolved around reaching a narrative end goal while avoiding being caught by an enemy. For example, the Ozobot returning a lost panda bear to its family while avoiding being caught by hunters (G03). **DIn6: Most groups were interested in a game of tag that involved the Ozobot as one of the players.**

We found a preference towards games with a variety of in-game tasks (9/16 concepts), for example, winning at UNO and walking a dog (G05) or collecting trash (G03) while racing not to get caught. **DIn7: Groups proposed complex games that included a variety of in-game tasks or mini-games.**

Nine of 16 concepts were related to the curricular themes. From those, we extracted the four themes: recycling (3/9), rescuing animals (2/9), escaping from a shark (1/9) and finding underwater treasure (1/9). **DIn8: When following the proposed curricular themes, children's concepts fall into four main narratives: escaping from a shark; recycling; rescuing animals; and finding underwater treasure.**

3.1.6 Initial Game Concept. Due to the Ozobot's size and features, we established that the game must be tabletop. Per **DIn6**, we established "tag" as the main game mechanic, with the Ozobot (**DIn1**), chasing the player's pieces around a gameboard. The game of tag also fits some of the preferences established in **DIn5**. Taking into account **DIn7**, **DIn4** and wanting to promote the inclusion of divergent ideas, we decided to include four mini-games, one per theme established in **DIn8**, that players would have to complete upon landing on specific spaces in the gameboard.

3.1.7 Workshop 4: Refining Game Mechanics. The fourth workshop focused on refining game mechanics for the four mini-games established in section 3.1.6. Each group was assigned one of the four themes identified in **DIn8** and provided with accessible worksheets laying out the game mechanics they had to define for their mini-game (Fig.2D). To steer them towards tabletop game mechanics, researchers asked children to think of how they would perform actions physically in-game and to write a list of game pieces they would prototype in the next workshop.

Observations: The added complexity of this workshop's worksheet contributed to some confusion among students. Researchers tried to mitigate this by redirecting groups to ideate and conceptualise their mini-games first, then filling out the worksheet. As in previous workshops, the necessity to reach a group consensus generated some conflicts. For example, G06ND2 unwillingness to compromise on his ideas and behaviours his group saw as disruptive (waving around worksheets and hiding under the table) culminated in a philosophical discussion about game prizes and what is most important in life - money, health, or family **[O2.2]**. In a more extreme example, when all of G02ND6's group but him reached a consensus, he got upset asking to move groups. After the researcher's prompting, the group included some of his ideas, which calmed G02ND6 down **[O2.4]**. However, we also witnessed groups autonomously developing strategies to mediate these discussions **[O2.5]**. G03ND4 proudly showed the research team how whenever someone in her group wanted to talk, they only had to put a hand in the middle of the table to receive the others' attention. In a different approach, group 12 used a handshake game to determine who got to make each decision within their design process (Fig.3C).

3.1.8 Workshop 5: Prototyping and Playtesting. The final workshop had children physically prototype their mini-games (Fig.2E). Researchers provided them with various recycled materials and classic game pieces, such as cardboard, foam, dice and hourglasses, to use alongside their school supplies. Once the prototypes were complete, researchers and teachers directed groups to change tables and playtest each other's games. This activity gave researchers a clear picture of how children envisioned gameplay.

Observations: The more hands-on approach of this workshop was well received by the children. The list of game pieces from the previous workshop guided groups through prototyping. For example, G08NT2 checked off items on the list as the group completed them, and G08NT3 divided tasks among her group and checked in with them often **[O2.3]**. There were still some disparities in terms of labour division **[O2.6]**. In one case, G11NT4 did not speak the local language and spent most of the session prototyping pieces unrelated to the group's game. In the end, the teacher helped the

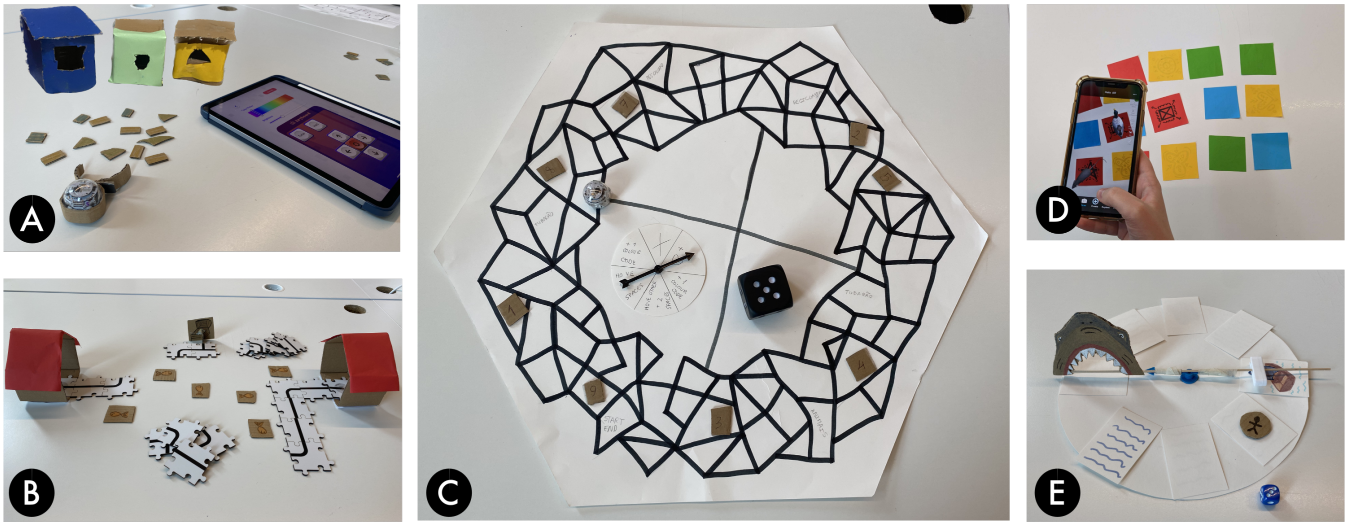

Figure 4: Initial Prototype. (A) Recycling mini-game, (B) Finding Underwater Treasure mini-game, (C) Gameboard, (D) Rescue Animals mini-game, (E) Escaping the Shark mini-game.

group incorporate them. Neurodivergent students and their neurotypical peers took different approaches to the task list. While the first focused on perfecting a single artefact to the utmost degree, the latter was more concerned with completing all the game pieces on time **[O5.2]**. After taking ownership of the shark game piece, G06ND2 spent most of the session prototyping it to an impressive level of detail. His group allowed him complete creative control and praised him for his work **[O4.1]**. G02ND6 spent most of the workshop colouring the gameboard of his team's prototype. This task completely encapsulated him, and when done, he went on to help colour the house G02NT4 had built (Fig.3D).

Analysis of Mechanics and Prototypes: Two researchers analysed the resulting 16 mini-game concepts by gathering photographs of prototypes (Workshop 5) and worksheets (Workshop 4) on a digital whiteboard and inductively coding them for ideas and game mechanics, and then identifying interesting ideas for game development and trends.

The recycling theme generated three sports-inspired mini-games in which players would attempt to score goals with trash into recycling bins (G03, G07, G13). **DIn9: The recycling mini-game is most often conceptualised as sports-like.**

Rescuing animals varied widely in its execution, with concepts inspired by roll-and-move games (G04, G16), UNO (G09) and open-world video games (G02). Escaping from the shark always took on a "tag" mechanic, with students puppeteering a shark figure and remote controlling the Ozobot to escape it. **DIn10: The escaping the shark mini-game associated with "tag".**

Finding underwater treasure was enhanced narratively with marine animal characters. However, only G16 gave it a concrete mechanic inspired by roll-and-move games.

The following observations were present in two to five prototypes but were considered noteworthy by the researchers analysing them. **DIn11: Fish are seen as obstacles. DIn12: Boats are seen as safe spaces. DIn13: Hearts are used to represent lives. DIn14: Prizes are most often money or money-like.**

3.2 Iterative Game Prototyping

Following the co-design workshops, we initiated an iterative game prototyping cycle, creating and evaluating prototypes that leveraged the identified design insights to generate further insights and improve subsequent prototypes.

3.2.1 Initial Prototype. For the first version of the game, we focused on gameplay rather than aesthetics. The game followed the initial concept, detailed in section 3.1.6. This prototype (Fig.4) included a game board where the Ozobot moved freely along black lines. In contrast, the players moved, in turns, according to a die, across the spaces between those lines, attempting to reach four highlighted mini-game spaces while evading the Ozobot. Upon landing on a mini-game space, players would play the corresponding mini-game:

(1) Escaping the Shark: One player would move a pawn between six cards while another rotated a pinwheel decorated as a shark. The player would win or lose when the shark landed on the pawn based on the current card's content, a boat or water (**DIn12**). This single-player game was luck-based and technology-free.
(2) Finding Underwater Treasure: Two teams compete to create paths for the Ozobot to reach a treasure chest, using the same puzzle pieces as in the workshops (Section 3.1.6). Each team must build their path around fishes, which the other team has laid out (**DIn11**). This game explored problem-solving and time-based challenges.
(3) Recycling: One player would remote-control an Ozobot (**DIn3**), with a shovel attachment to sort trash, and the other would attempt to score goals (**DIn9**), with the sorted pieces. This two-player collaborative game engaged players' abilities to control the Ozobot and their fine motor skills.

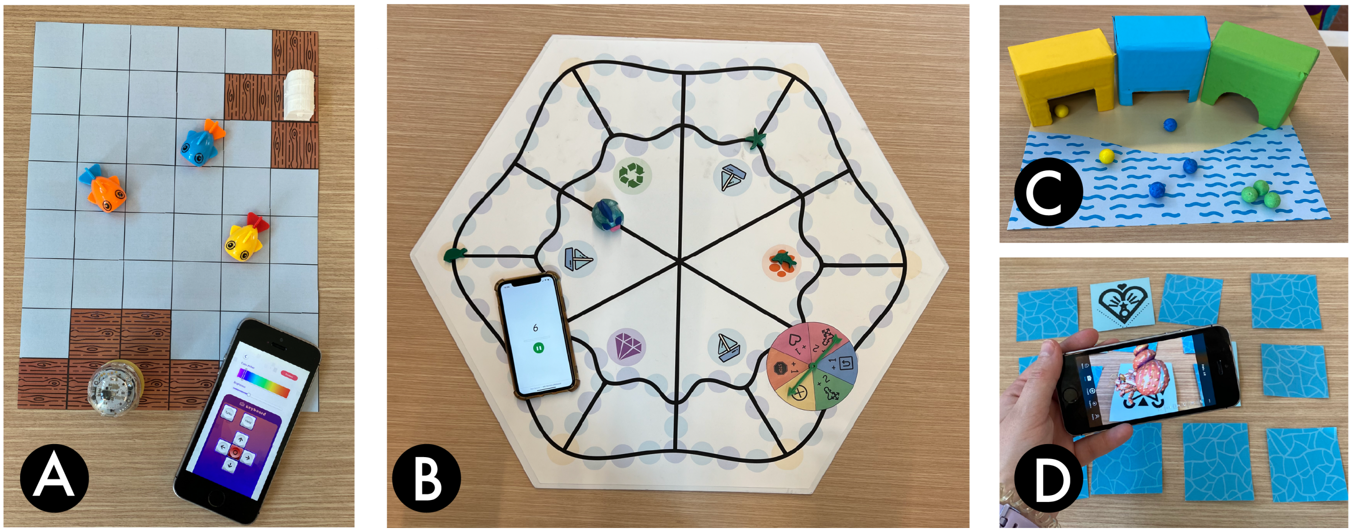

Figure 5: Final Prototype. (A) Treasure mini-game, (B) Gameboard, (C) Recycling mini-game, (D) Animals mini-game

(4) Rescuing Animals: Players compete in a classic game of concentration, enhanced with AR (**DIn1**). After flipping each card, players looked at a tablet screen to see the 3D model of an animal. This multi-player game utilised the Halo AR app [5] and leveraged players' memorisation skills.

After winning a mini-game, players received a coin-shaped token (**DIn14**) and spun a prize wheel. Rewards from the prize wheel included extra movement, heart-shaped tokens that protected players against a shark attack (**DIn13**), and colour-code stickers to control the Ozobot shark.

3.2.2 Playtest with Game Designers. We held a playtest of the initial prototype with seven game design Master's students (one with ADHD). After a short introduction to the project, participants played the game and voiced their thoughts while a researcher took notes, which two researchers collectively analysed.

Participants considered the game engaging but with potential for improvement at this early stage. The Ozobot was the session's highlight, particularly the option to remote-control it. Mini-games took most gameplay time, making the main game mechanic less memorable. Furthermore, players who were not participating in a particular mini-game grew bored. **DIn15: Waiting while watching other players engage with the game for long periods can generate disengagement.**

Participants also pointed out balancing issues in some of the mini-games, such as the collaborative aspect of the Recycling mini-game. They posed that if a player only missed the Recycling token, the rest of the group could indefinitely stall their progress by refusing to cooperate effectively. **DIn16: Including a collaborative mini-game in a competitive game could promote sabotage among players.**

3.2.3 Final Prototype. After implementing changes based on the playtest with game designers and improving the game's overall aesthetics, we conducted several internal critique and playtest sessions with researchers within our lab, making incremental changes to improve pacing and balancing.

Our final game prototype (Fig.5) adapted the concept detailed in section 3.1.6, reducing the number of mini-games to three. Following **DIn15**, we aimed to avoid entirely single-player mini-games, and given that the mechanic of "Escaping the Shark" was quite similar to that of the gameboard, we decided to remove this mini-game, transplanting its theme to the gameboard. In a redesigned gameboard, players moved their animal-shaped pawns simultaneously (**DIn15**), according to an automatic digital die, to ensure fairness, while evading an Ozobot representing the shark. We also made changes to the remaining mini-games and gave them simplified names:

(1) *Treasure* lost the two-team aspect due to lack of available Ozobots. Becoming a multi-player game in which those not controlling the Ozobot placed fish figurines on a grid (**DIn15**), and the player attempted to avoid them using the Ozobot Evo app [6] remote control to reach the treasure without touching the fishes.
(2) *Recycling* lost its collaborative aspect (**DIn16**) and focused on the sport-like element (**DIn9**). Becoming a two-player finger-football-style game in which players attempted to score goals with small coloured styrofoam balls in the correct recycling bin.
(3) *Animals* was virtually unchanged, except for minor balancing and aesthetics tweaks.

The prize wheel and tokens received aesthetic improvements and added simplification to the colour-code stickers (**DIn3**).

3.3 Evaluation Workshop

We held an evaluation workshop with the four classrooms engaged in the co-design process and a fifth control class to playtest the resulting game. We aimed to answer the research question: *How*

[5] https://haloar.app/

[6] https://ozobot.com/evo-app/

does the resulting game support inclusive play, for both neurodivergent and neurotypical children?

The fifth class was a fourth-grade class from the same school. Class 5 (ages 9-10 M=9.53 SD=0.51) includes groups G17 through G19 and seven neurodivergent students — detailed demographics in Table 2. Ninety-nine children (25 ND) tested the game in groups of 4 to 6 (the same ones as in the co-design workshops, if applicable), with one researcher accompanying each group. The researcher facilitated and observed gameplay.

3.3.1 Data Collection and Analysis. We video-recorded the sessions, with one camera pointing at each group, and asked each researcher to write field notes after each session. Due to technical issues, we could not retrieve usable video data from groups 10, 14, 16, and 18. We conducted a Reflexive Thematic Analysis [8] of the video footage using deductive coding. After familiarising themself with the field notes, the lead researcher analysed the resulting 19 hours of footage, writing a detailed transcript, which was then used as a guide to find noteworthy moments in the videos, further analyse and code them. We focused on instances of interaction between participants, contextualising each occurrence with its participants and corresponding moments in gameplay.

3.3.2 Observations. We identified five themes in our analysis: (1) Emotional Reactions; (2) Engagement and Disengagement; (3) Reinterpretation of Game Rules; (4) Conflicts and Resolutions; (5) Help and Camaraderie.

Emotional Reactions: We observed many emotional reactions tied to in-game events, such as a player losing or winning a mini-game. The *Animals* mini-game prompted many reactions from players, specifically when a pair of cards was revealed **[O3.3]**.

The most prominent was the celebration of both self and others **[O4.1]**. Players cheered on winning groupmates through claps and high-fives. Neurotypical players celebrated their wins through verbal expressions and gestures. Meanwhile, neurodivergent players showcased their excitement more frequently with screams and dynamic movements **O5.3**. For instance, upon finding pairs in *Animals*, G09NT4 exclaimed *"I did it!"* while G06ND2 daces around in celebration.

	Class 5 (4th grade)
Age	9-10, M=9.53, SD=0.51
Gender	9 girls and 10 boys
Groups	G17, G18, G19
Neurodivergent	G17ND3 - ODD G17ND6 - ADHD G18ND3 - ID G19ND1 - ADHD G19ND3 - ADHD and ODD G19ND7 - Speech Difficulties G19ND8 - ADHD

Table 2: Demographics of the classes participating in the control groups. ID: Intelectual Disability, ODD: Oppositional Defiant Disorder, ADHD: Attention Deficit and Hyperactivity Disorder

Players reacted negatively to in-game misfortunes, such as getting their pawn eaten by the shark, not starting first, losing, or another player winning a mini-game **[O4.2]**. These reactions, both verbal and non-verbal, expressed frustration and disappointment. For example, G12NT2 raised his arms to his head upon hitting a fish in *Treasure*, and G03ND4 lamented that there was "no point in trying" in *Animals* due to the number of cards left.

Instances of gloating occurred sporadically and, in all but one instance, came from neurotypical players **[O4.3]**. Including G07NT4 saying *"Take that, G07NT1!"* after winning *Recycling*, and G12NT2 laughing as a groupmate loses *Treasure*.

The groups from the control class reacted less and with less intensity to in-game events **[O6.1]**. For instance, upon winning *Treasure*, G17NT2 merely smiles.

Engagment and Disengagement: Our observations focus on explicit displays of engagement and attentive behaviours, such as going quiet to hear an explanation or leaning over to watch a moment in gameplay.

Both neurodivergent and neurotypical children were engrossed in gameplay in similar fashions, particularly during moments when players were taking in-game actions **[O1.2]**, such as moving pawns on the gameboard, piloting the robot in *Treasure* or attempting to score in *Recycling* (Fig.6B), and, most of all when a pair of cards was revealed through AR **[O3.3]**. Notably, most groups created a huddle over the cards in *Animals*, paying close attention to the AR figures on the tablet (Fig.6A).

Brief moments of disengagement were common with both neurotypical and neurodivergent players. During transitions between mini-games, players often disengaged and lost focus **[O1.3]**. For instance, while mini-games were set up, G08NT2, G08NT3, and G08NT4 arm wrestled, and G02ND1 and G02NT5 turned to look at another table. A change in in-game activities tended to recapture the players' attention. In cases of more extended periods of disengagement, players returned to gameplay after being called by the researcher to take an in-game action.

Groups in the control class had less explicit portrayals of engagement and disengagement **[O6.1]**. However, two students in this class did disengage completely from gameplay, removing themselves from the playtest for the rest of the session due to disinterest or in reaction to conflicts **[O6.2]**. Among them was G19ND3, who left her group's table, ignored calls from the researcher, and never returned.

Reinterpretation of Game Rules: Though researchers explained the game rules to the group, enforcement was left up to the children. Rather than moving their pawns on the gameboard spaces (Fig.6B) according to the number displayed on the digital die, several players explored alternative forms of movement, disregarding the number on the die **[O3.4]**. These behaviours included G12ND1 gliding her pawn over the lines, G05ND4 moving her pawn across the board to a mini-game space, G06ND1 moving between line intersections, and G09NT1 "walking" her pawn like a doll. Fellow group members did not acknowledge or react to these changes to the game rules save for three instances.

Notably, in every control group where players moved their pawns irregularly, there was an instance of conflict related to these movements **[O6.3]**. For instance, G19NT6 sternly tells G19ND1 to stop moving her pawn in such a way.

Figure 6: Game Evaluation Workshop. (A) Group huddle during *Animals*. (B) Pawn movements on the gameboard, (C) Engagement and Disengagement in *Recycling*

Conflicts and Resolutions: Conflicts among group members arose during the playtest, though most were brief. Our observations showcased verbal arguments among neurodivergent and neurotypical students alike. Neurotypical students initiated conflict through accusations of cheating, by teasing others, and by insisting they should be the first to play a mini-game. Neurodivergent students started arguments related to the violation of their boundaries, classroom decorum, and sharing inactive game pieces. As an example, G17NT5 accused G17NT2 of cheating for attempting to take back a card in *Animals*, and G01ND1 takes the Ozobot out of G01ND3's hands, saying 'It's not just for you!".

Arguments occurred mainly in the transition period between mini-games or the gameboard, sometimes relating to the mini-game they had just played or were about to play. Most instances of conflict ended without a clear resolution, as players returned to gameplay once a new activity started **[O2.7]**. If not, researchers intervened, asserting their version of events or attempting to minimise the issue's importance **[O2.4]**. For instance, a researcher breaks up a discussion about who should play first by reminding group 15 that going last has advantages.

Help and Camaraderie: Even while actively competing against each other, we observed instances of collaboration and support **[O2.8]**. We observed groupmates discussing strategy during gameplay, notably as they placed the fish for the *Treasure* mini-game. Even in moments that did not require collaboration, such as when a player was piloting the robot in *Treasure* or attempting to score points in *Recycling*, groupmates chimed in with tips and warnings. In one case, G01NT5 used her colour-code to save G01NT2 from the shark.

Neurotypical students encouraged neurotypical and neurodivergent groupmates, chanting their names and cheering, as they took in-game actions, like choosing a card in Animals or piloting the robot in *Treasure* **[O2.9]**. However, when players faced adverse outcomes, such as losing a mini-game or being caught by the shark, comfort came from the researcher through hugging and verbal reassurance **[O2.10]**. For example, G17NT2 gave G17ND6 tips during *Treasure*, but when she lost, the researcher assured him there would be more games.

As with other kinds of outward expression during gameplay, these instances of camaraderie were less visible in the control groups **[O6.1]**.

4 DISCUSSION

This paper describes the co-design process of a tabletop robotic game with 80 neurodiverse children. Through iterative design cycles, we refined the prototypes and subsequently returned to the same children to evaluate the final prototype. To shed light on the implications of being involved in the co-design process, we also evaluated the game in a new neurodiverse classroom. Results indicate that involving neurodiverse children in multiple co-design sessions stimulates their interpersonal relationships and enhances their group work skills. Children often engaged in negotiation and conflict resolution as well as helping and working together towards solutions. The success of these co-design workshops can be attributed mainly to the multiple hands-on approaches tailored to children's different skills. Below, we discuss our research reflections on conducting co-design efforts in neurodiverse school contexts and how games can promote inclusive experiences. Finally, we provide broader implications for the design of future inclusive technologies and limitations of our work.

4.1 Co-Designing in a Neurodiverse School Context

Answering the first research question, we explore how the co-design process affected neurodiverse groups and how they and the classroom setting shaped it.

4.1.1 Conflicts and Groupwork. Over five months of co-design workshops, we observed several changes to the dynamics of the participating neurodiverse groups, particularly regarding conflict management and group work. Though the teachers had initially mentioned that group work was a common practice within their classrooms, they confided that they had neglected this skill after observing the first few co-design workshops.

In Workshop 1, children struggled to make decisions as a group. Disagreements were met, with each child shouting their opinion at the others to convince them. Some attempted to decide by a majority rule, but this only alienated those in the minority **[O2.1]**.

Researchers and teachers had to step in with suggestions to promote consensus by simply proposing combinations of everyone's ideas **[O2.4]**. Workshop 2 required less joint decision-making and more action-based tasks. Still, a few disagreements arose regarding choosing a song for the creative activity or deciding who got to pilot the robot. These were not as significant, as they found that control over the activities could be shared in turns, and their music tastes had significant overlap **[O2.3]**. For Workshop 3, the perceived preferences of the proxy worked to streamline design decisions. We observed groups patching together different ideas into a single game concept, accommodating neurodivergent students' attachment to their proposals **[O2.3]**. We noticed apparent differences in group dynamics when we returned to the classroom after a few weeks for workshop 4. Two groups autonomously established explicit social dynamics to facilitate group work **[O2.5]**. Groups embraced deeper discussions, getting to the root of their disagreements and reaching a consensus without outside intervention **[O2.2]**. In the final workshop, all groups divided tasks among members, with each child picking a game piece they were keen on bringing to life **[O2.6]**.

As explored by previous work [15, 16], conflict is a necessary part of group work. It is through negotiation and constructive disagreement that design insights emerge and solutions that are favourable for diverse groups are created. Throughout the sessions, we observed groups move from destructive fights into constructive disagreements as they built negotiation skills and became accustomed to their groupmates. Inclusive group work was not a skill we could single-handedly teach or engineer into our activities; it was acquired through accumulating experiences with the group members and learning how to adapt, listen, and embrace diversity in the design process.

4.1.2 Co-desiging in Classroom Environments. Classrooms are often used in co-design projects with neurodiverse children due to ease of access and existing infra-structure. Nevertheless, classrooms can impose restrictions that limit the potential of designing inclusive games [54].

Our classrooms had limited space, with desks and chairs constricting movement. Making significant changes to the classroom layout for our short co-design workshop would disrupt the flow of the school day. So, we opted for tabletop activities that participants could complete while sitting at a desk with their groups. Our methodological approach took inspiration from several previously reported co-design activities in classroom contexts [15, 25, 35, 38, 39]. However, we noticed a tendency towards physical expression among participants. This context did not nurture that. Children, particularly neurodivergent children, often got up from their chairs, looked at different groups, or even danced around. These behaviours could have been further explored in the co-design process[25] through methods such as bodystorming [49] or even creating games that made greater use of floor space if the classroom context had been permissive.

Teachers' personality traits and pedagogical practices greatly influence children's inclusion and respect towards others. A more directive teacher guides the children during the creative process, showing them videos of DIY artefacts needed for the game (Class 3). However, this teacher was also demanding, making children work individually and follow instructions precisely. Contrarily, a very affectionate teacher can coddle the class, even referring to her neurodivergent student as *"special ones"* (Class 2). This teacher claimed children showed a *"special respect"* towards their *"more different"* peers. Her constant encouragement of neurotypical students to help neurodivergent peers created more empathy among children, but it also led to stigmatising behaviour.

These limiting factors should not be seen as deterrents to co-designing within education settings. Being aware of them may allow researchers to proactively negotiate autonomy within their design processes, widening creativity.

4.1.3 Co-designing with Neurodiversity. The choice of our co-design methodology was rooted in the profiles of the participating children, as described by their teachers. We also made adaptions within and between sessions to resolve any issues that arose during fieldwork. Therefore, our co-design methodology was in itself influenced by the participating neurodiverse groups.

Prior work in co-design with neurodivergent children and within neurodiverse contexts proposed adapting existing practices to the specific needs and preferences of the participating children [25, 51]. Reading and writing support can enable equitative participation for neurodivergent children who struggle with these skills. We employed this practice in accessible worksheets, where each text prompt had an accompanying pictogram, and each answer box had enough space for a drawing. At first, children disregarded these features and attempted to write, as was common practice in the classroom. However, once they realised drawing was an option, neurodivergent children expressed relief. Furthermore, even children proficient at writing took this root, enabling more creative outcomes. These diverse options supported children with a range of possibilities to express and convey their thoughts and ideas creatively **[O3.2]**.

Workshop 3 had great success in creating empathy and inclusive game concepts through expanded proxy design [39]. This methodology was initially developed for co-design within mixed-visual groups and extended to other visible disabilities. In its proposed form, proxies would have physical characteristics related to their differences. However, neurodivergent children, for the most part, do not have physical indicators of their conditions. Adapting the initial methodology, we opted for various proxies and the vehicle of a presentation worksheet to share their characteristics. This slightly altered approach proved fruitful in conveying neurodivergent needs and reflecting them in-game concepts **[O3.1]**.

4.2 Promoting Inclusive Play Experiences

Exploring the second research question, we reflect upon the co-designed game, its characteristics, and how it promoted engagement and inclusion during gameplay.

4.2.1 Game and Gameplay. Aiming to provide the neurodiverse groups with agency over their gameplay, we based our game design on the co-design outputs rather than prior work regarding neurodiverse or neurodivergent gaming. This approach aimed to centre children's shared interests and strengths [51] while leveraging the "cool" factor of technology towards creating an engaging and inclusive experience [9, 51]. Overall, children displayed interest in the game, commenting on gameplay, leaning over for a better view, and reacting expressively to in-game events. They showcased emotions associated with gameplay, including joy and frustration. However, the most prominent displays were of celebration, indicating a positive gaming experience.

Contrasting with many scenarios within the field of mixed-ability gaming, children opted for a competitive game. The tendency towards cooperative scenarios, specifically asymmetrical ones [23], comes from an attempt to balance players' differences in skills and abilities to avoid unfair advantages and frustration [10]. However, cooperative scenarios can also lead to further conflict because one player's win is tied to another's performance. Nevertheless, we honoured children's preference for competitive games and tried to balance this competition [9] by including challenges that matched different skill sets. We still observed children rooting for each other, celebrating others' wins, and helping groupmates, indicating they were not consumed by their desire to win **[O4.1, O2.8, O2.9]**. When it came to the end of the game, children tended to disperse, disregarding who the overall winner was. With one group even stating *"We all win!"*. We speculate that **the role of the Ozobot shark as a common enemy to all players** might have encouraged this sense of group and promoted such prosocial behaviours. The many **micro-wins and micro-losses throughout gameplay** allowed all players to feel capable and celebrate their successes, leading to more inclusive gameplay.

The diversity that neurodiverse groups brought to their game designs was a direct attempt to accommodate the preferences of various group members, which we took on to incorporate preferences from the 80 participating children. Prior work [7, 51] indicates that we should attempt to include neurodivergent children's preferences within play scenarios. Only an equally expansive and diverse game concept could accommodate this when dealing with such a large and diverse group. **Mini-games were quick and constantly changing**, meaning a child's favourite mini-game always felt within reach, and any they particularly disliked would soon be over. As observed in co-design workshop 2, having a diverse set of activities allowed neurodiverse groups to remain engaged for more extended periods. The mini-game that scaffolded the most interaction was *Animals* **[O3.3]**, with groups reacting to pairs of cards being revealed and captivated by the AR figures on the tablet screen. *Animals* was also the game that required **constant participation of all group members, took the longest to be played, and employed technology novel to all players**. *Treasure* was children's favourite mini-game. Players rushed to this mini-game space and asked to play it first. *Treasure* also allowed for all players to participate, even promoting group strategy. However, **winning or losing this game came down to the individual performance** of the player piloting the Ozobot. This level of agency was engaging, and **the multiplayer aspect enabled entertainment for the whole group**. On another note, the effect of the change in mini-games on the game's pacing was akin to a loading screen in a retro video game, a moment to pause. We observed that children tended to disengage during these moments of transition but quickly returned to gameplay when a new activity started **[O2.3]**. We do not perceive such moments as harming gameplay; contrarily, we pose that they may have provided neurodivergent children with an opportunity to self-regulate by removing themselves from the group context [16]. **Playing different mini-games allowed children to disengage for brief periods**, reloading their cognitive resources and returning enthusiastically to play the upcoming mini-game.

4.2.2 Sustained Inclusion through Appropriation. The most surprising aspect of the evaluation workshop was how children who participated in the co-design process, particularly neurodivergent children, reinterpreted the game's rules **[O3.4]**. In all but two cases, this happened while moving pawns on the gameboard, permissible by the tangible nature of the game. We understand this behaviour as a form of appropriation [12]. Neurodivergent children took a system that did not suit their needs (i.e., difficulties with counting) and changed it to accommodate their skills. This behaviour was only challenged in the newly formed control groups, save for a specific instance where the change in movement was perceived as an unlawful attempt to evade the shark **[O6.3]**.

The co-design groups had a more profound knowledge of how the game was built and how their decisions impacted its creation. Some even outwardly expressed their feelings of ownership over the final prototype, claiming *"It is ours! I already know how to play!"*. We propose that this ownership, coupled with the competence and empathy built through the co-design process, empowered children to appropriate the final game prototype. Other instances of appropriation follow similar patterns of finding fixes for their own unmet needs. In the control group, there were fewer instances of appropriation, and when it occurred, it was followed by accusations of cheating from group mates.

We found appropriation to be an avenue for adaptable play scenarios, which are essential within neurodiverse groups [15, 51], but complex to implement within a game prototype. Leveraging appropriation within game design allowed players to create bespoke solutions to emerging problems. This led to a more inclusive gaming experience, adaptable to changing needs and interests. Our results highlight the relevance of involving children early in the design process, both to ensure that products meet their needs and preferences and to increase the likelihood of successful appropriation afterwards.

4.3 Broader Implications: Inclusion as a Process

The undercurrent of our reflections is the impact of continued group interactions among neurodiverse children. Inclusive practices built over time through co-design workshops allowed neurotypical children to understand the needs of their neurodivergent classmates better, to grow used to their differences, and to learn to accommodate their preferences. Regardless of how much thought was put into their inclusive features, a single co-design intervention or playthrough of a game cannot change group dynamics. It is only through reoccurring interactions that these goals can be achieved.

Our work highlights a novel dimension to the impact of co-design on inclusion. Inclusion is a process. Building inclusive practices throughout co-design workshops may strongly contribute to participants' inclusive behaviours while interacting with the resulting artefacts. These insights contribute to ongoing efforts within HCI, HRI, and Inclusive Education research, proposing a new perspective on the function of group co-design activities within mixed-ability settings.

4.4 Limitations & Future Work

Co-design as a methodology is by nature aimed at generating bespoke solutions that suit a particular person or group of people [A]. We argue that the situated knowledge it generates has a verifiable impact on co-designers throughout the process. Within the specific context of neurodiverse groups, there is no such thing as a representative sample due to the inherent diversity of such groups [B]. We recognise that neurodivergence is a broad spectrum, as our sample of 18 neurodivergent children, all within the same school, only partially encompasses it. Other factors, such as the specific socioeconomic environment, gender-based conflicts, the novelty of the robot, and the presence of children who were not fluent in the local language, also impacted the co-design process. Thus, we do not argue that our game design is directly transferable, exactly as is, to a different context and population. Still, our co-design tools and practices can serve as a basis to engage neurodiverse groups in classroom activities. We contribute a methodological and philosophical approach to promoting inclusion within diverse groups. We propose that the focus should not be on the inclusive artefacts generated by participatory approaches but on the process itself and how we can design it to support the process of inclusion.

In future work, we aim to test the co-designed game with more control groups and with the co-designers after a more extended period, further cementing our findings, discarding its novelty effect, and exploring if continued play could impact inclusion akin to that of the co-design process. Despite the longitudinal nature of this work, the scope of this project only encompassed measuring impact within the co-design process's timeline and activities. Future work could extend upon this, measuring long-term impact, by following up the process with monitoring of inclusive behaviours in and out of the classroom. This could be achieved through in-classroom observations and periodic interviews with teachers and parents. Furthermore, taking on our current findings regarding inclusion through appropriation, we intend to explore the inclusive potential of games with flexible rules and how to leverage appropriation within gameplay.

5 CONCLUSION

In this work, we take on the lens of neurodiversity, aiming to explore the inclusive potential of co-designing a robotic game with neurodivergent and neurotypical children. Our work addresses the challenge of building inclusive gaming experiences for neurodiverse groups through participatory interventions.

We present an exploration of neurodiverse group work and game design preferences through co-design workshops. From these, we derive a series of design insights that inform the design of a tabletop robotic game. We highlight children's preferences towards competitive games incorporating various in-game activities, such as mini-games. Our reflections on these workshops showcase how continued group work promoted better understanding and group dynamics among neurodiverse groups.

Our evaluation workshop demonstrated the ability of co-designed robotic games to promote engagement and inclusive play within neurodiverse groups. Our exploration of co-design bias through a playtest with a control group not involved in the design workshops revealed an unexpected consequence of children's ownership. When met with accessibility challenges, children in the co-design group appropriated the game's features to accommodate their needs. A new pathway for inclusion was forged through this appropriation process, which was consensual among groups. We underscore the importance of the process of building inclusion, which no single artefact or activity can replace.

We found that inclusive co-design activities promoted a gradual familiarisation within neurodiverse groups, who autonomously developed strategies to accommodate each member while motivated by game design's creative and technological aspects (RQ1). Furthermore, we found that the neurodiverse classroom posed physical and social limitations to inclusive co-design. Still, strategies such as Expanded Proxy Design and providing reading and writing support aided in counterbalancing these (RQ1). Additionally, we found that both neurodivergent and neurotypical children could enjoyably and inclusively participate in gameplay, though their interactions with it differed (RQ2). Finally, we found that several aspects of the final game design were particularly conducive to inclusive play, such as the technological elements, presence of a mutual enemy, and fast-paced/varied game mechanics; however, the continuous collaboration among group members seemed to be the key factor that promoted inclusion through appropriation (RQ2).

Our work builds on previous efforts towards creating inclusive play experiences for mixed-ability groups and neurodivergent games research, offering a new perspective by combining neurodiverse players, robots and a co-design approach. Our findings underscore the processual nature of inclusion — though researchers and educators have an essential role in creating inclusive methods and tools, inclusive play can only be achieved through prolonged engagement between the players, who learn to be more inclusive over time.

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