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Design of boundary objects to improve communication in pediatric care

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ABSTRACT: Designing healthcare interventions for children with complex health needs often overlooks the perspectives of key stakeholders, including children. Collaborative design is essential for creating solutions that integrate diverse viewpoints and bridge communication gaps. However, prior studies lack tools to align stakeholder perspectives in pediatric care. This study introduces Octo, an educational toy, as a boundary object to enhance communication among children aged 4 to 10 with congenital heart disease (CHD), their parents, and healthcare providers. Octo evolves from a prototype to a functional educational tool, fostering engagement through play while promoting health literacy and stakeholder collaboration. This research through design (RtD) demonstrates the effectiveness of boundary objects in advancing inclusive, child-led interventions and collaborative healthcare design.

KEYWORDS: boundary object, communication, participatory design, child-led design, user centred design

1. Introduction

Designing healthcare interventions for children with complex health needs requires collaboration among children, parents, and healthcare providers. Effective communication between these groups ensures that interventions are accessible, relevant, and tailored to their needs (Chow et al., 2024; van de Riet et al., 2024; Barbazi et al., 2025a). However, differences in expertise, language, and perspectives can create communication barriers, highlighting the need for tools that facilitate collaboration and bridge these gaps. Boundary objects, first conceptualized by Star and Griesemer (1989), provide shared reference points that help stakeholders interpret and engage with information based on their expertise while maintaining a common function (Star & Griesemer, 1989; Rhinow et al., 2012; Groot & Abma, 2021; Saidi et al., 2023). These adaptable tools foster collaboration throughout and beyond the design phase. While some prototypes may temporarily function as boundary objects by integrating stakeholder feedback, they typically stabilize into final products. In contrast, boundary objects remain flexible, continuing to support knowledge-sharing and stakeholder engagement after implementation. Certain products and services can also serve as boundary objects if they facilitate sustained collaboration among stakeholders, making them particularly effective in healthcare contexts (Rhinow et al., 2012; Lauff et al., 2020; Krishnakumar et al., 2022; Codner & Lauff, 2024). For example, Islind et al. (2022) examined how a symptom tracker monitoring children's fever—based on caregiver input—helped parents record symptoms and temperature changes. This enabled children to express discomfort through caregiver observations, ensuring providers assessed their condition and made informed decisions. Similarly, Tribot et al. (2023) showed that familiar toys and family photos as transitional objects provide comfort and build trust in clinical settings, strengthening stakeholder relationships. These examples illustrate how boundary objects remain adaptable, fostering shared understanding and improving coordination within the care team (Terlouw et al., 2022).

Octo, an educational toy for children with congenital heart disease (CHD), demonstrates how boundary objects enhance communication in pediatric care. Through iterative feedback, it balances developmental needs, medical accuracy, and usability to foster collaboration and improve health literacy. This study, as part of a multi-phase research, applies a Research through Design (RtD) approach (Frayling, 1994; Godin & Zahedi, 2014) and follows the five stages of Design Thinking (DT): empathizing, defining, ideating, prototyping, and testing (Brown, 2008). While earlier phases involved empathizing, defining, and ideating, this study focuses on the prototyping and testing, where iterative refinement aims for Octo to function as a boundary object to enhance pediatric health literacy and stakeholder collaboration.

2. Background

2.1. Boundary objects

Boundary objects have proven valuable in social relations, education, design, and healthcare (Fox, 2011; Terlouw et al., 2022; Velleu et al., 2023). Research highlights their role in improving communication and coordination across disciplines. Their adaptability makes them particularly useful in multi-stakeholder environments, where diverse groups interpret and apply them based on their needs. For example, shared databases and classification systems foster cooperation (Albrechtsen & Jacob, 1998), while standardized forms enable cross-departmental coordination (Carlile, 2002), effectively bridging gaps between technical and nontechnical users (Lundgren, 2021). In healthcare, boundary objects such as patient records, visual aids, and interactive tools enhance provider-patient communication and care coordination (Allen, 2009; Islind et al., 2022; Terlouw et al., 2022). They also translate research into practice and engage marginalized groups by promoting dialogue and emotional responses (Melo & Bishop, 2020). Examples include 'care pathways' that streamline clinician-patient communication (Allen, 2009; Håland et al., 2015), risk assessment scales and patient wristbands that improve hospital coordination (Melo & Bishop, 2020), and 'referral pathways' that distribute roles among providers to enhance collaboration (Dowrick et al., 2021). Co-produced boundary objects, developed with input from multiple stakeholders, better capture diverse perspectives and foster engagement by addressing power dynamics (Fleming et al., 2023; Melville-Richards et al., 2020).

While adaptability is essential in pediatric care, boundary objects remain underexplored despite the communication challenges caused by children's developmental needs and knowledge gaps. Pediatric care involves stakeholders with varied expertise levels, and differing terminology can make key information hard to understand, especially for children. For example, children may perceive routine procedures as frightening, leading to distrust or resentment toward caregivers and providers. However, developmentally appropriate explanations can foster comfort and trust. Children struggle to articulate their feelings, while parents—the primary decision-makers—may lack a full understanding of their child's condition or the provider's treatment plan. This disconnect complicates communication and care coordination (Burns et al., 2022; Rodts et al., 2020). In pediatric care, boundary objects align perspectives, ensuring that interventions support children's understanding and foster collaboration.

2.2. Health literacy

Health literacy is crucial for effective pediatric care, helping children, parents, and healthcare providers understand, communicate, and make informed health decisions. Higher health literacy improves adherence, disease management, and reduces hospitalizations; for example, asthma education lowers emergency visits by 31% and hospitalizations by 54% (Rodts et al., 2020; Burns et al., 2022; Liu et al., 2022). However, traditional approaches such as text-heavy brochures and verbal instructions often fail to engage young children (Rodts et al., 2020; Burns et al., 2022), highlighting the need for interactive, engaging, and adaptable design solutions. Creative, activity-based approaches make healthcare interventions more effective and developmentally appropriate, especially for children aged 4–10. Playful co-design approaches encourage children to contribute to tool design, fostering a sense of ownership (Druin, 2001; Teela et al., 2023). Family-centered strategies ensure interventions accommodate different cognitive levels, making them practical for a range of users. Incorporating design activities with children, caregivers, and providers personalizes health literacy interventions, promoting better adoption and engagement (Barbazi et al., 2025b). Ultimately, these strategies enhance collaboration and improve healthcare outcomes for children with complex conditions.

3. Methodology

This study adopts a Research through Design (RtD) approach (Frayling, 1994; Godin & Zahedi, 2014), using Design Thinking (DT) as a process to guide the iterative development of Octo (Brown, 2008). RtD views design as a research tool, where each iteration generates insights beyond product refinement. By applying design as inquiry, this study explores how RtD informs the creation and evolution of boundary objects to improve communication in pediatric care. As part of a multi-phase research, this study follows five DT stages: empathizing, defining, ideating, prototyping, and testing. Earlier phases addressed empathizing, defining, and ideating, while this paper focuses on prototyping and testing. In this phase, prototypes functioned as boundary objects, allowing children, parents, and providers to interact, provide feedback, and refine the design toward an effective final boundary object product. Through iterative prototyping, RtD enables continuous adaptation—refining the artifact and its theoretical foundation—to enhance communication and understanding in pediatric CHD education.

3.1. Study context

This study explored CHD, a structural heart abnormality from birth, and the creation of boundary objects to enhance communication and collaboration in pediatric care. CHD affects around 40,000 newborns annually in the U.S. and requires lifelong management (CDC, 2024). As a chronic condition, CHD demands seamless coordination among healthcare providers, parents, and children. However, complex medical information often creates communication barriers. Children and families struggle to understand and navigate their healthcare journey, while providers face challenges simplifying medical terminology into child-friendly language (Arya et al., 2013; Rodts et al., 2020; Burns et al., 2022; Barbazi et al., 2025b). These challenges are magnified by varying levels of understanding among stakeholders and the difficulty of engaging young children in health discussions and research (Banker & Lauff, 2022; Vang & Lauff, 2024). Boundary objects bridge these gaps by aligning perspectives and creating accessible, engaging, and informative resources. Such tools empower children and stakeholders to participate in managing CHD, making medical concepts easier to grasp in both design and real-world application.

3.2. Overview of the design process

The project began in May 2021 as a collaboration between the Department of Pediatrics and the School of Product Design, addressing two key questions: 1) How might we enhance health literacy for children aged 4-10 with CHD and their families? and 2) How might we design a child-led intervention that fosters engagement among children, caregivers, and healthcare providers? The current project is approved by the University of Minnesota IRB (STUDY00020670). From 2021 to 2023, the research followed the first three stages of DT—empathizing, defining, and ideating—to understand stakeholder needs and inform the design of a boundary object for children, parents, and healthcare providers (including physicians, nurses, and child life specialists). Observations at Camp Odayin, a camp for children with heart disease, consultations with providers, shadowing at the M Health Fairview Pediatric Explorer Clinic, and analysis of existing medical education tools identified key CHD education challenges, including lack of engaging, age-appropriate tools, insufficient caregiver resources, and the need for interactive, child-led communication strategies. Our findings reinforced the importance of play-based learning in enhancing engagement, simplifying medical concepts, and improving understanding. Play provides children with CHD—who often have limited opportunities for traditional play—a way to explore, learn, and interact with other stakeholders. To address these challenges, in prior phases, we explored various design concepts, including an AR/VR doll, a LEGO heart, a 3D heart model with an app, a heart flow lamp, an animated toy with a screen, and a check-in journal app. After evaluating them based on engagement, feasibility, and educational impact, we developed an initial prototype as a boundary object to facilitate communication in pediatric CHD. The prototype integrated play, interactivity, and sensory engagement to enhance learning. Throughout development, prototypes served as boundary objects, enabling stakeholders to engage, provide feedback, and refine design features.

3.3. Design principles

The design of Octo is guided by four design principles—emotional, educational, social, and physical (Figure 1); Octo fosters engagement, simplifies medical concepts, and supports collaborative learning.

These principles emerged from the thematic analysis of stakeholder feedback, where affinity clustering identified key aspects (Braun & Clarke, 2012). The emotional aspect provides comfort and reduces anxiety through familiar, child-friendly interactions, making medical learning less intimidating. The educational component simplifies complex medical concepts into developmentally appropriate content, enhancing health literacy for children and parents. The social principle encourages children to discuss their condition with peers, parents, and providers, reinforcing knowledge through interactions. The physical aspect integrates interactive elements, allowing hands-on exploration of medical concepts through interactive play. By leveraging toy-based play as a shared language, Octo allows children to explore medical concepts through role-play, while caregivers and healthcare providers use it to guide discussions and explanations (Díaz-Rodríguez et al., 2021; Gjærde et al., 2021).

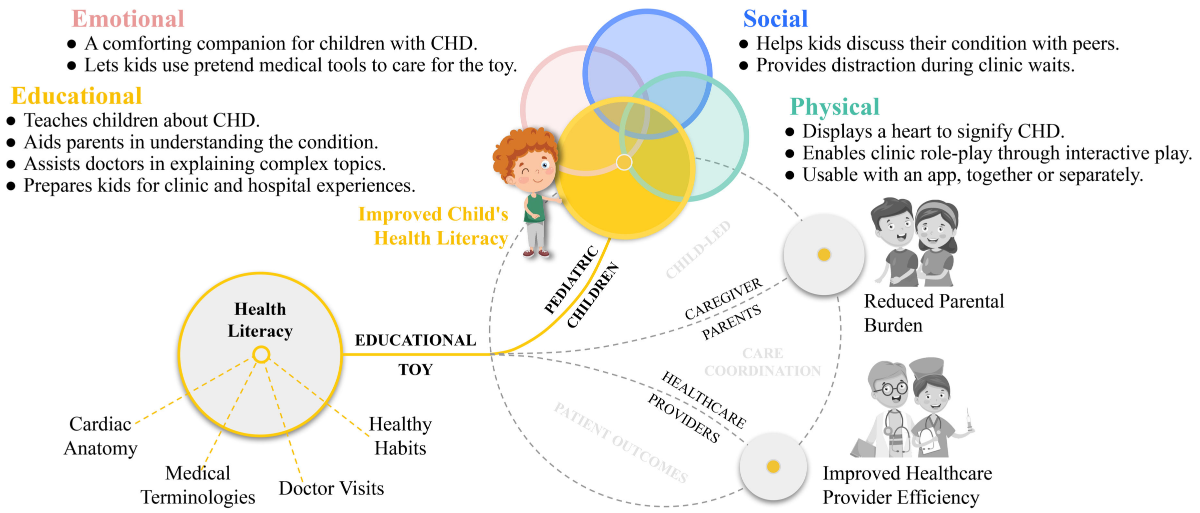

Figure 1. Goals and objectives for the toy design

Our market research confirmed that a character-driven companion was more engaging than general medical toys and helped design child-friendly representations of internal body parts. Research on digital health tools revealed that while gamification and ‘open world’ interactions engage children, most existing tools do not cater to younger audiences. Hospital-based educational tools are often text-heavy, limiting accessibility for non-readers. Stakeholder interviews with families and child life specialists highlighted that clinical teaching methods rely on generic dolls with medical tools (e.g., EKG stickers), but there is a lack of CHD-specific interactive learning tools/toys. These insights shaped Octo’s design, ensuring it is customized, developmentally appropriate, and interactive, bridging gaps in pediatric health education. As a boundary object, Octo translates complex medical information into accessible and engaging experiences through iterative refinement. It provides children aged 4–10 with hands-on learning opportunities that mirror real healthcare experiences, helping them understand cardiac anatomy, medical terms, and what to expect during doctor visits. Octo helps children understand their care through pretend play, acting as healthcare providers in role-playing scenarios. This hands-on, engaging approach encourages self-expression and deepens understanding of CHD in a supportive, playful environment. Studies show that informed children experience less anxiety and are better prepared for medical situations (Witt et al., 2023; Rashid et al., 2021).

By embedding health education into play, Octo enhances children’s health literacy, reduces parents’ educational burden, and minimizes the need for extensive explanations during medical appointments (Burns et al., 2022; Rodts et al., 2020; Arya et al., 2013). Octo combines a plush toy with a digital app, creating a hybrid tool that promotes communication and engagement. The plush provides emotional comfort, while the digital features support storytelling and hands-on learning (Fontijn & Mendels, 2005; Ponticorvo et al., 2020). Research suggests that transitional objects, like plush toys, reduce stress and anxiety in children undergoing medical treatments (Bloch & Toker, 2008; Tribot et al., 2023). The development of Octo involved design iterations from low to high fidelity to ensure it effectively serves as a boundary object. The next section details Octo’s design evolution and insights gained during the prototyping process.

4. Prototype evolution

We developed three Octo variations (Figure 2) to facilitate communication and gather feedback from children, caregivers, healthcare providers, and designers, including product design graduate students and researchers from the College of Design. Each prototype iteration was first tested with healthcare providers for medical accuracy, then with children and parents to refine engagement, usability, and developmental appropriateness. Early concepts were presented to healthcare providers, who evaluated anatomical accuracy, procedural representation, and terminology suitability for CHD education. Their feedback refined the heart structure, medical tool representation, and clarity of key health concepts. Once validated for clinical accuracy, prototypes were introduced to children through play-based interactions, assessing their engagement, attention, and comprehension of medical concepts. Insights from children and parents informed modifications to toy features, interactive elements, and storytelling, ensuring the design remained both educational and emotionally supportive.

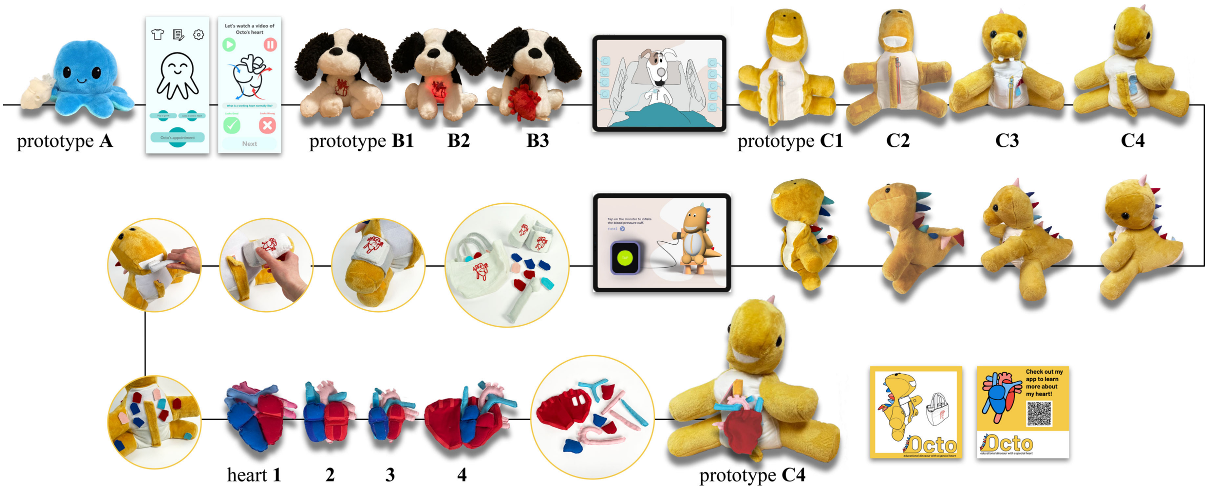

Figure 2. Octo's physical and digital evolution from conception to the present

4.1. Prototype A: plush octopus with removable 3D-printed personalized heart

The selected Octo prototype (Figure 2) was a plush octopus with a removable 3D-printed heart stored inside its body. The heart provided a tangible way for children to understand their cardiac anatomy and CHD, with each heart customized from medical scans to reflect a child's specific condition. The design integrated an app with educational content on heart health, medical procedures, and emotional expression. The octopus symbolizes intelligence and uniqueness, encouraging children to embrace their individuality with confidence and positivity. Its head functioned as an open bag, allowing easy 3D-printed heart placement and storage while reinforcing the child's identity. However, the octopus's anatomy did not align with human physiology, limiting its effectiveness for teaching about the body. Additionally, 3D printing was time-intensive and struggled to depict internal heart defects accurately.

4.2. Prototype B: plush dog with various hearts

Building on the lessons from Prototype A, we confirmed that plush toys effectively engage young children. However, the 3D-printed heart proved too complex for their understanding. To address this, we developed Prototype B, a plush dog with multiple heart designs and an 'open world' app enhanced with augmented reality (AR) that promoted healthy habits and improved anatomical accuracy. The familiar dog character resonated with children, aligned better with human physiology, and simplified heart placement. To refine the heart design, we created three versions (Figure 2): B1) Glowing Heart with AR, which illuminated and interacted with the app to teach about their heart conditions; B2) Heart Patch with AR, representing specific heart defects tailored to each child; and B3) Plush Heart & Zipper, featuring a removable heart inside the dog with a zipper, symbolizing open-heart surgery scars. The Plush Heart & Zipper proved most promising, offering a tangible, emotionally supportive way for children to engage with their condition. However, the plush dog raised safety concerns. Children might confuse playtime with real-life medical procedures and mimic these actions on real pets. This led us to explore alternative designs and imaginative characters while maintaining educational value.

4.3. Prototype C: plush dinosaur with puzzle heart

Building on earlier prototypes, we conducted a survey to assess user preferences for character choice and heart placement. Most respondents preferred placing the heart inside the body—parents valued this for preventing loss, healthcare providers for realism, and children for the interactive 'hide and seek' feature. The survey presented three character options: a dinosaur, a dog, and an unknown creature. While the dog received the most votes for its seated posture and less gendered appearance, we selected the dinosaur, the second-most popular option, as a safer alternative due to concerns previously identified in Prototype B. This decision highlights the role of expert feedback in aligning design choices with medical goals and the importance of stakeholder input in guiding effective designs. The dinosaur prototype aimed to enhance learning while addressing the safety concerns identified with the dog. Its engaging design captured children's imaginations and aligned better with human anatomy. A spacious chest allowed easy placement of the puzzle heart, fostering interactive, hands-on learning. Through iterative testing, we developed and refined four versions of the dinosaur and its puzzle heart (Figure 2).

The heart featured pieces representing the four chambers and inflows/outflows, allowing rearrangement to show different CHD states. Early versions used Velcro to hold the pieces, but testing showed Velcro made them hard to maneuver and prone to sticking, complicating use and production. To create a friendly look, we simplified the face by removing freestanding teeth from an earlier version and adjusted the head and eye proportions. We replaced the chest zipper with Velcro based on healthcare provider feedback, though some feedback opposed this change. The arms were shortened, widened, and tilted inward for easier hugging, while a bean bag in the tail improved stability. We chose a cheerful yellow color for its gender-neutral appeal, evoking warmth and positivity, while blue and red accents reinforce heart-related themes. The plush texture provides comfort, promoting relaxation during therapeutic learning. Integrating the puzzle heart into a tactile, beloved toy encourages deeper engagement through play. Like Prototype B, Prototype C pairs with an app and AR features to enrich learning.

Within the app, children can explore familiar 'home' and 'clinic' environments, encountering medical procedures like EKGs, blood pressure checks, and echocardiograms. Visual cues guide them to interactive areas where they learn healthy habits, such as brushing Octo's teeth using AR features. A new feature, 'MyHeart Experience,' allows children to explore heart anatomy with a digital puzzle that mirrors Octo's physical heart assembly, reinforcing their understanding of heart function. Octo's medical bag includes plush tools—a blood pressure cuff, echo wand, EKG stickers, and a toothbrush—familiarizing children with common procedures. A guidebook further explains each tool and procedure, enriching learning through play, as shown in Prototype C4. Octo's soft, vibrant design and interactive heart puzzle encourage engagement, offering a comforting, hands-on introduction to cardiac anatomy. Children can open Octo's chest to explore a heart model, assemble its parts, mimic procedures, and role-play as a doctor, empowering them to learn about their health playfully (Figure 3).

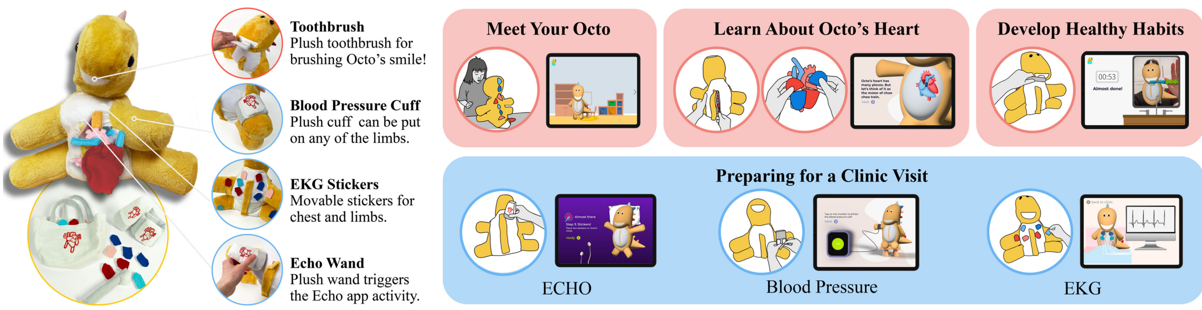

Figure 3. Key interaction points of Octo's digital and physical prototypes with children

The name 'Octo,' inspired by the earlier octopus prototype, resonated with stakeholders and was kept for the dinosaur version, now with eight spikes symbolizing 'eight' in Greek and Latin. As a boundary object, Octo collects feedback from children, parents, and healthcare providers, refining its design and educational content. Figure 4 shows how Octo bridges stakeholders' differing terminology, supporting communication and educational use.

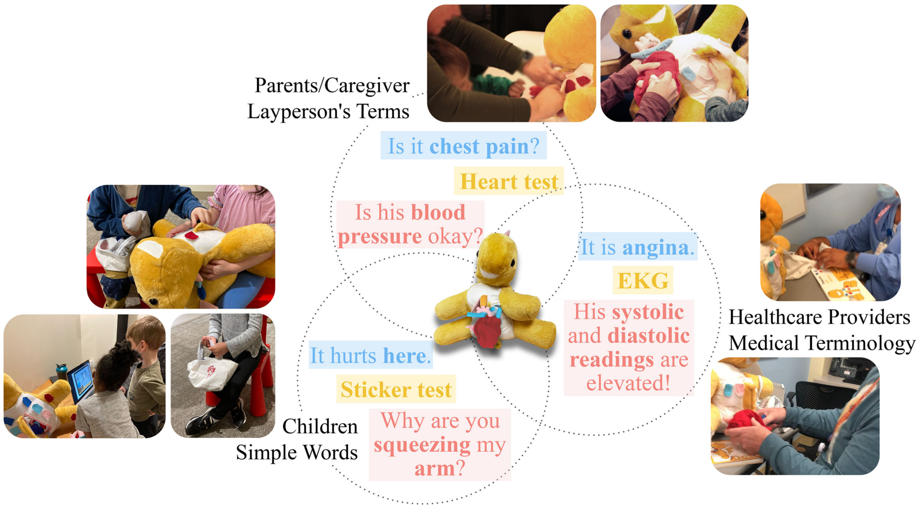

Figure 4. Octo bridging communication among stakeholders

5. Discussion

This study advances the understanding of boundary objects in healthcare by designing Octo, an educational tool to enhance communication in pediatric care. As part of a multi-phase study, Octo fulfills dual roles: first, as a boundary object that translates complex medical information into accessible, engaging, and developmentally appropriate formats for children; second, as a series of iterative prototypes functioning as boundary objects during the design process to gather stakeholder feedback and optimize design. This duality underscores Octo's unique contribution to addressing both communication and design challenges in pediatric care. Guided by two research questions—How might we enhance health literacy for children aged 4–10 with CHD and their families, and how might we design a child-led intervention that fosters engagement among children, parents, and providers?—this study applies Star and Griesemer's (1989) boundary object concept to illustrate how playful, child-led design aligns the perspectives of pediatric key stockholders. Communication gaps in pediatric healthcare, especially in conveying complex medical information to children with developmental differences, remain a persistent challenge (Burns et al., 2022; Fairbrother et al., 2016; Rodts et al., 2020; Teela et al., 2023; van de Riet et al., 2024). Octo addresses this need by simplifying medical concepts and fostering engagement through interactive and playful design elements (Gjærde et al., 2021). By involving children aged 4–10 with CHD as active participants in the design process, Octo not only facilitates understanding but also fosters ownership, confidence, and self-efficacy in managing their care. This aligns with research emphasizing the importance of child-led design in pediatric care (Druin, 2001; Shin & Holtz, 2019, 2020; Teela et al., 2023; van de Riet et al., 2024; Chow et al., 2024).

Furthermore, the iterative development of Octo prototypes reinforces its role as a boundary object. Independent prototypes served as tools to gather feedback from key stakeholders, including children, parents, providers, and designers. Healthcare providers ensured medical accuracy while children and parents refined usability, emotional engagement, and developmental appropriateness. Designers synthesized these insights to create functional, visually engaging prototypes that met the diverse needs of stakeholders. The process began with low-fidelity prototypes—simplified models to explore key concepts and functionality. These early models, evaluated by providers for medical accuracy, informed the creation of high-fidelity prototypes that closely resembled the final product. High-fidelity prototypes enabled actionable feedback from pediatric participants, demonstrating their effectiveness in engaging children and refining design (Codner & Lauff, 2024; Banker & Lauff, 2022; Norman, 2013; Carlile, 2002). This approach ensured that Octo balanced safety, accuracy, and usability while addressing stakeholders' needs (Groot & Abma, 2021).

Octo also offers an engaging alternative to traditional educational tools such as brochures and verbal instructions, which often fail to resonate with children (Burns et al., 2022; Fairbrother et al., 2016). Its playful and interactive features simplify complex medical concepts, fostering understanding and curiosity. Through storytelling and the integration of physical and digital elements, Octo equips caregivers and providers with tools to explain health concepts effectively, promoting shared learning and collaboration (Arya et al., 2013; Díaz-Rodríguez et al., 2021; Fontijn & Mendels, 2005; Witt et al., 2023). This shared understanding fosters trust and strengthens stakeholder collaboration, creating a more cohesive and empathetic approach to pediatric care (Terlouw et al., 2022; Groot & Abma, 2021).

Key design features—signifiers, mental models, and affordances—make Octo approachable and engaging for children. Signifiers, like distinct colors and textures, guide interactions. For instance, Octo's puzzle heart uses color coding (blue/red) to help children understand cardiac anatomy. Mental models leverage familiar play activities, like puzzles, to align children's understanding with assembling a heart. Affordances, such as the Velcro opening of Octo's plush chest, encourage hands-on exploration of internal anatomy (Codner & Lauff, 2024; Norman, 2013). Embedding these elements early and iteratively ensures that Octo reflects children's experiences while meeting the informational needs of parents and providers (Arya et al., 2013; Fairbrother et al., 2016). Prototypes highlighted the importance of aligning design complexity with developmental capabilities. For example, a medically precise 3D-printed heart model recommended by providers proved too intricate for young children, limiting engagement. In contrast, color-coded puzzle pieces and simplified terminology encouraged participation and aligned with children's cognitive abilities. This finding supports research showing that overly detailed designs can overwhelm children and hinder engagement (Fairbrother et al., 2016; Son et al., 2008). By balancing simplicity with accuracy through storytelling, Octo creates moments of joy/relief for all stakeholders, transforming the stress of medical care into a positive and empowering experience.

5.1. Conclusion and implications

This research through design study demonstrates the potential of a boundary object like Octo to address communication and design challenges in pediatric care. By translating complex medical information and enabling iterative stakeholder feedback, Octo balances design complexity with usability, safety, and accuracy for young children. These findings offer insights for creating child-led tools that enhance communication, health literacy, and collaboration. Future research will refine Octo's features, assess its long-term impact, and explore adaptations for other pediatric conditions like asthma and diabetes. Beyond healthcare, Octo's iterative design process highlights the broader value of boundary objects in multidisciplinary challenges. Its principles provide a foundation for creating tools that facilitate interdisciplinary communication in contexts like education and community engagement. By fostering collaboration and demonstrating scalability in complex, multi-stakeholder settings, Octo exemplifies the transformative potential of boundary objects in designing inclusive and impactful solutions.

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