Accessibility by Design: Designing Inclusive Technologies with and for People with Intellectual Disabilities

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presented by
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I certify that except where due acknowledgement has been given, the work presented in this thesis is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; and the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program.

Leandro Soares Guedes
Lugano, 22 March 2024

To all of our amazing participants

Accessibility allows us to tap into
everyone's potential

Debra Ruh

Abstract

Digital accessibility and assistive technologies have been employed to improve the experiences of individuals with intellectual disabilities in multiple settings. This work explores the application of these technologies in informal learning settings, with an emphasis on museums and creativity, to create engaging and knowledge-rich experiences. In this doctoral dissertation, participants with intellectual disabilities are engaged in all design steps, with the final goal of understanding their needs and preferences and developing and evaluating prototypes with them. When establishing procedures and activities to engage them in the co-design process, it is essential to consider their abilities, needs, and rights. The study is structured into four main parts: (1) Methodological Frameworks and Design, which underscores the use of improvisation and scaffolding techniques to adapt the design process to the participants' requirements; (2) Digital and Interactive Technologies, examining the role of Augmented Reality (AR) through AIMuseum, accessible applications through ACCESS+, and social robots in making museum content more understandable and engaging for the participants; (3) Creativity and Multisensory Integration, enabling users to interact with art content using multiple senses and leveraging their creative expression with Artificial Intelligence (AI), a Multisensory Diorama (MSD), and with a multisensory self-representation box, called Empowerbox, fostering self-expression and creativity; (4) Discussion and Conclusions, where research questions are addressed and reflections are offered. In these studies, we included important stakeholders: cultural mediators, who play an essential role in building narratives to engage visitors while describing the content of items on display; educators and support workers, who have close contact and provide help and the necessary scaffolding for participants; and a psychologist, who analyze emotional, cognitive and social processes and behavior. These stakeholders are also involved in the design team, and by examining their participation, interaction, and role, this project seeks to better understand the needs of final users and find more effective ways to listen to their voices and have them as active partners. This doctoral dissertation contributes to the Human-Computer Interaction (HCI) field by providing

methodological insights and practical applications for inclusivity in technology design. Also, it advances the understanding of how digital and interactive technologies can be leveraged to make informal learning and cultural institutions more accessible and engaging for individuals with intellectual disabilities.

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I would like to provide special recognition to my co-authors, research partners, and the diverse stakeholders who enriched this project, including dedicated educators, museum curators, and psychologists. Your varied perspectives have greatly enhanced the quality and depth of my research.

My parents deserve heartfelt mention for their immense sacrifice and support, as they traveled from Brazil to witness my defense. Your love and dedication have been my pillars of strength and inspiration. I also extend my gratitude to my family members who, despite the distance, have always supported and cheered for me.

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The international network of collaborators, including peers from the W3C

Accessible Platform Architectures Working Group and the Cognitive and Learning Disabilities Accessibility Task Force, as well as the a-STEP COST Action: Advancing Social Inclusion through Technology and Empowerment, deserve special recognition for their contributions.

Last but not least, thanks to my friends and peers who supported me throughout the 53 months of my doctoral journey, and to those who attended my defense. Your presence and encouragement have been invaluable.

To everyone who has supported me on this journey, I express my gratitude once again. Your contributions have helped me reach this academic achievement and significantly shaped the person I am today.

Contents

List of Acronyms

AAC Augmentative and Alternative Communication

AI Artificial Intelligence

AR Augmented Reality

COGA Cognitive and Learning Disabilities Accessibility Task Force

HCI Human-Computer Interaction

ICT Information and Communication Technology

MSD Multisensory Diorama

PD Participatory Design

QR Quick Response

RQ Research Question

SR Social Robots

TTS Text-To-Speech

UI User Interface

UX User Experience

W3C World Wide Web Consortium

WCAG Web Content Accessibility Guidelines

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Introduction

This doctoral research was undertaken to understand how to involve people with intellectual disabilities in co-designing knowledge-driven engaging experiences with technology, in the context of museums and a focus on informal learning and creativity. To this end, numerous sessions were organized in conjunction with museum visits, either before, during, or after these visits. Furthermore, sessions dedicated to creative expression were also held, emphasizing their importance for inclusion and social interaction. This introductory chapter sets the stage by presenting the background, context, and motivation behind this research, outlining the proposed study, research questions, and objectives. It also provides an overview of the doctoral dissertation, detailing its contributions and challenges, and finally, a publication overview.

1.1 Background, Context, and Motivation

Approximately one billion people, constituting around 15% of the global population, live with some form of disability, a figure projected to increase due to aging and population growth [211]. Despite being the world's largest minority group, people with disabilities often encounter barriers to full participation in society [315], including limited access to technologies and services. Individuals with disabilities experience notably reduced access to and utilization of information and communication technologies compared to those without disabilities [218]. Within the broader spectrum of disabilities, individuals with intellectual disabilities represent a particularly marginalized group, characterized by a lack of literature and research attention [178]. Despite their considerable presence and distinct needs, the availability of resources and support specifically designed for them is lacking, further deepening their isolation from technological progress and opportunities for social and economic engagement.

The World Health Organization defines intellectual disabilities as a significant reduction in the ability to understand new or complex information, learn new skills, and have a notable impact on daily life, beginning before adulthood [315]. People with intellectual disabilities experience the world uniquely, and their non-conventional forms of communication often limit their social interactions, learning opportunities, and recreational activities. Regrettably, mainstream research often adopts a deficit-oriented approach, viewing disability as something to be fixed or repaired [256] rather than embracing the diverse experiences and perspectives of individuals with intellectual disabilities. This perspective tends to marginalize disabled individuals and their families, portraying them as deficient in skills, confidence, and societal contributions [231]. This approach risks ignoring the voices and needs of some of the most vulnerable members of society and often results in their representation by proxies or caregivers instead of directly acknowledging their perspectives [154].

The development of accessible and assistive technologies holds the promise of improving the inclusion and independence of people with disabilities. Despite this potential, such technologies are not widely used, and there is a notable gap in their availability and acceptance. For example, an alarming 75% of companies in the UK's FTSE 100 Index do not meet the minimum web accessibility standards, leading to significant financial losses estimated at over $147 million [211]. This highlights the need for greater attention to and investment in technologies that can bridge these gaps and support the diverse needs of individuals with disabilities in different areas.

The need for awareness is also crucial in our education system. Surveys on the lack of clear learning objectives and faculty knowledge in teaching accessibility in computing faculties highlight a significant educational gap [117, 267]. In our survey applied in Switzerland [117], 77% of faculty members don't teach accessibility as it's not central to their courses, while 21% feel they lack sufficient knowledge. Among those who do teach accessibility, 62.5% focus on evaluating web page standards and heuristics, and 50% of those address the technological barriers faced by people with disabilities. These findings are echoed in research addressing perceptions of web accessibility, the accessibility of library services, and the effectiveness of web accessibility tools [123, 177, 328]. The sparse literature on methods for incorporating accessibility into curriculum [103, 174, 184, 244], alongside best practices for its integration in university settings and beyond [3, 230, 307], underscores a broader narrative. This narrative is further enriched by discussions on curriculum strategies, institutional culture's impact on curriculum changes [31, 160], and the emphasis on accessibility rights by the Convention on the Rights of People with Disabilities [210]. Additionally, understanding the spectrum of cognitive and learning disabilities is essential for creating inclusive educational and cultural spaces [192].

In my personal trajectory, the journey towards a deep engagement with accessibility and Human-Computer Interaction (HCI) began during a semester in Portugal as part of my bachelor's degree, where I was first introduced to this captivating field of research. My subsequent engagement in conducting in-person experiments during my master's and my volunteer work with support centers was already leading me to accessibility without my clear understanding back then. My solid background in computer science provided me with a solid foundation in traditional research methodologies, a skill set that was further enhanced by my experiences in teaching. During my tenure as an educator and as part of the "Service Center for People with Specific Educational Needs" commission, I worked with students with disabilities, including students with learning disabilities, and I encountered the evident limitations of conventional technical solutions and methodologies. The opportunity to pursue a PhD came with the discovery of the BEST project: Beyond Screen Readers and Alt Text: Designing Multisensory Alternatives to Text for Different Reading Abilities. This project seemed the perfect opportunity, as the project was challenging, interesting, and useful, giving me the motivation I needed to start, and now, to deeply engage with the exploration of this research area. As I reflect on my journey, I am increasingly convinced of the importance of reevaluating our approach to computer science and accessibility, aiming to bridge the significant gap and narrow the digital divide.

It is noteworthy to highlight that this doctoral dissertation started a few months before the COVID-19 pandemic breakdown. Several strategies were used to try to mitigate the effects of the lockdown, such as transitioning to outdoor open-air meetings, efforts to conduct online video calls, and implementation of safety protocols. The exploration of this adaptive process and the concept of improvisation will be discussed in Chapter 3. The uncertainty was there for an extended duration, spanning over a year. This resulted in side projects, the postponement of the defense date by one semester, and new partnerships with institutions due to the necessity to find novel working modalities. More details will be elaborated upon in Chapters 3 and 10. Finally, as stated, this doctoral dissertation has posed an incredible challenge but has also provided a unique lens through which to view computer science, profoundly altering my understanding of accessibility and its potential to transform lives.

1.2 The Proposed Research

This doctoral dissertation explores the intersection of accessibility, assistive technologies, and research methodologies to understand how to involve people with intellectual disabilities in the process of co-designing technology-driven, engaging experiences, within the context of museums – as public spaces – and also creative environments. The dissertation focuses on leveraging digital and interactive technologies and exploring multisensory experiences and creativity, consequently enhancing the experience of individuals with intellectual disabilities.

A central part of this research is the participatory design approach, which actively involves participants with intellectual disabilities – whenever possible – in every step of the design process. This inclusive approach aims to deeply understand the needs, preferences, and creative aspirations of individuals with intellectual disabilities, ensuring that the developed technologies are both accessible and engaging. By doing so, the research seeks to establish effective procedures and activities that respect and amplify the abilities, needs, and rights of these individuals, positioning them not just as users but as co-creators of their technological engagements.

The dissertation unfolds across four comprehensive parts. Part I, "Methodological Frameworks and Design", discusses how the research was conducted and the adoption of improvisation and scaffolding techniques to tailor the design process to the unique requirements of participants with intellectual disabilities. This methodological approach is crucial for fostering an inclusive design environment where participants can contribute meaningfully.

Part II, "Digital and Interactive Technologies", delves into the exploration of Augmented Reality (AR) through the AIMuseum application, accessible applications via ACCESS+, and the integration of Social Robots (SR) serving both as a co-facilitator during museum visits and as a mechanism for gamification. These technologies are examined for their potential to make museum content more understandable and engaging, thus addressing the diverse ways individuals with intellectual disabilities interact with the activities.

In Part III, "Creativity and Multisensory Integration", the emphasis is on engaging users with content through multiple senses and fostering creative expression. This section highlights the role of a Multisensory Diorama (MSD) in informal learning inside museums, introduces Empowerbox – a tool designed for multisensory self-representation to foster creativity and self-expression, and introduces Artistic Fusion – the use of Artificial Intelligence (AI) in creative expression, underscoring the importance of creative expression to engage with and understand museum content.

Finally, Part IV, "Discussion and Conclusions" synthesizes the findings, addressing the research questions and offering reflections on the co-design process, the effectiveness of the implemented technologies, and their impact on the museum experience for individuals with intellectual disabilities. Important stakeholders, including cultural mediators, educators, support workers, and psychologists, play a pivotal role in this process, contributing to a holistic understanding of the needs and experiences of museum visitors with intellectual disabilities.

An overview outlining the structure, content, and main publications of this doctoral dissertation is available in Figure 1.1. This dissertation contributes to the field of HCI by offering methodological insights and practical applications for inclusivity in technology design. Furthermore, it advances the understanding of how digital and interactive technologies can be employed to make cultural institutions more accessible and engaging for individuals with intellectual disabilities, ultimately enhancing their participation in and contribution to cultural and creative experiences.

In the composition of this doctoral dissertation, the first-person singular pronoun has been employed in the Introduction, Discussion, and Conclusions sections to convey personal insights and reflections. Conversely, the use of the first-person plural pronoun in the remaining chapters reflects the collaborative nature of the work, underscoring the collective efforts and contributions of the team involved. Furthermore, this doctoral dissertation uses American English writing to maintain consistency with the majority of the published research papers. However, original publications were also available in British and Australian English (e.g. [115, 276]).

1.3 Research Questions and Objectives

This doctoral dissertation seeks to tackle more than one Research Question (RQ), subdividing the main research questions into smaller and more manageable ones. The main questions are the following:

- RQ 1: How can we design technologies with and for people with intellectual disabilities?
- RQ 2: How do people with intellectual disabilities access and engage with digital and interactive technologies?
- RQ 3: How can we leverage technologies to engage people with intellectual disabilities in creative expressions and multisensory experiences?

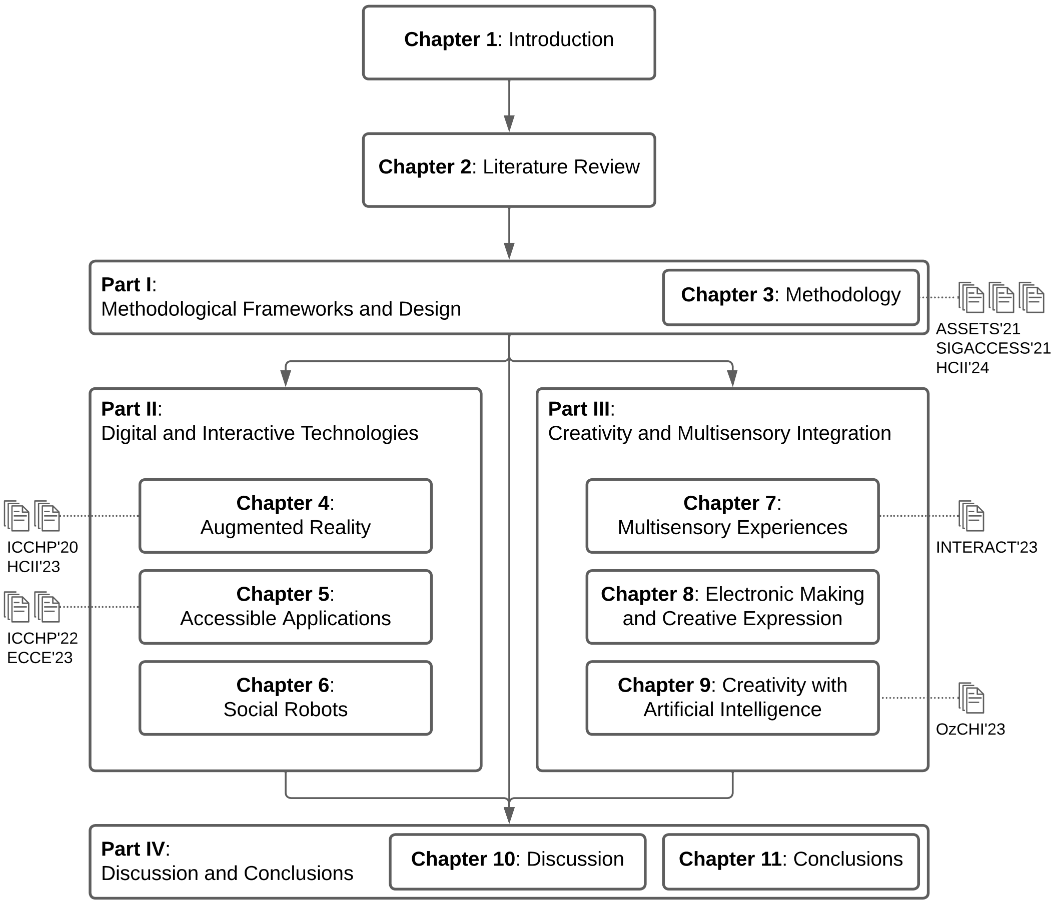


Figure 1.1. Diagram outlining the structure, content, and main publications of this doctoral dissertation.

To effectively address the main research questions, I segmented them into smaller and more manageable subquestions. This approach emerged as particularly beneficial during the writing of different papers, which included a deeper examination of existing literature, insights gathered from observation sessions, and feedback received from reviewers or during conferences. Through this process, additional research questions appeared, enriching the scope and depth of my investigation.

- RQ 1.1: How can we involve people with intellectual disabilities in Participatory Design?
- RQ 1.2: How can we involve people with intellectual disabilities in the evaluation of digital and interactive prototypes for museum visits?

- RQ 1.3: How can we use technology to involve people with intellectual disabilities in creative and multisensory experiences?
- RQ 2.1: How does the use of augmented reality influence the access to and engagement with museum content for individuals with intellectual disabilities?
- RQ 2.2: How does the use of accessible applications influence the access to and engagement with museum content for individuals with intellectual disabilities?
- RQ 2.3: How does the use of social robots influence the access to and engagement with museum content for individuals with intellectual disabilities?
- RQ 3.1: How do people with intellectual disabilities perceive and engage with a multisensory diorama?
- RQ 3.2: How can making an electronic multisensory personalized box allow creative expressions by people with intellectual disabilities?
- RQ 3.3: How can generative artificial intelligence be used to stimulate the creativity of people with intellectual disabilities?

The objectives of this study are:

- To Empower Participation in the Design Process: Engaging individuals with intellectual disabilities in all design steps, from conceptualization to prototype development and evaluation, to effectively understand their needs and preferences.
- To Adapt and Refine Co-Design Methodologies: Establishing methodological frameworks and design practices that include improvisation and scaffolding techniques tailored to the participants' requirements, and enhancing the inclusivity of technology design.
- To Investigate the Role of Stakeholders in Supporting Accessibility: Analyzing the participation, interaction, and impact of cultural mediators, educators, support workers, and psychologists in designing supportive and engaging learning environments.

- To Enhance Accessibility and Engagement in Museum Settings for Individuals with Intellectual Disabilities: Using digital and interactive technologies such as Augmented Reality (AR), accessible applications, and social robots to make museum content more understandable and engaging.
- To Foster Creative Expression Among Individuals with Intellectual Disabilities: Utilizing AI and personalized tools like the Empowerbox to support creativity and participation.
- To Enhance Multisensory Experiences in Museum Environments: Create and evaluate multisensory tools and experiences, such as multisensory dioramas, that allow individuals with intellectual disabilities to engage with museum content through auditory, visual, and haptic feedback.
- To Contribute to Human-Computer Interaction Knowledge: Offering methodological insights and practical applications for inclusivity in technology design, specifically within the context of cultural institutions and informal learning experiences.

1.4 Doctoral Dissertation Outline

1.4.1 Chapter 1

This chapter introduced background information, context, and the motivation behind the research proposed in this doctoral dissertation. It has detailed the various components of the study and presented a diagram that illustrates how these components are interconnected with the chapters and publications associated with this work. Furthermore, the research questions and objectives of this doctoral dissertation have been clearly outlined. In the following section, I will present the references and abstracts of the publications included in this doctoral dissertation and additional publications and contributions conducted during my PhD.

Earlier in this chapter, I provided a brief introduction to one paper [117] that delves into the critical issues surrounding teaching methodologies and accessibility within the Swiss educational system. Although the paper itself will not be deepened in the subsequent chapters, its relevance lies in establishing a foundational understanding of the challenges and considerations in enhancing accessibility.

In the following chapters, I will explore several research topics, examining the rationale behind the selection of each topic for study. I will comprehensively discuss the contributions and findings associated with these topics, highlighting their significance and impact on the field.

1.4.2 Chapter 2

This chapter carefully examines the intersection between individuals with intellectual disabilities, HCI, and accessibility, highlighting the limited but growing body of literature in this area. It highlights the challenges and advancements in including people with intellectual disabilities in HCI research and design processes, emphasizing the importance of developing technology that is accessible, empowering, and inclusive. The review covers several aspects, including the significance of support in formal and informal educational settings, and the role of technology and design in enhancing accessibility and participation.

The review explores the potential of co-designing methodologies and technologies like AR, AI, and SR in creating more inclusive environments for people with intellectual disabilities. It discusses how these technologies can be tailored to meet their unique needs and preferences, facilitating better access to information, learning opportunities, and social interactions. It also touches on the importance of museums and informal learning environments in promoting accessibility and inclusion, suggesting that these spaces can serve as vital platforms for engaging individuals with intellectual disabilities through interactive and multisensory experiences.

Finally, the chapter emphasizes the shift in paradigm toward more inclusive research and design processes that acknowledge the importance of direct participation and collaboration with people with intellectual disabilities. It advocates for ongoing efforts to bridge the gap in the literature and practice, advocating for innovative solutions that address the barriers faced by people with intellectual disabilities and leverage their strengths and abilities, thus contributing to their empowerment and full participation in the world of technology.

1.4.3 Chapter 3

This chapter contains the first part of this doctoral dissertation, called Methodological Frameworks and Design.

The methodology outlines an inclusive design process aimed at developing technology solutions for and with people with intellectual disabilities. It emphasizes the importance of understanding the unique needs, preferences, and abilities of people with intellectual disabilities to create accessible, engaging, and empowering experiences. The methodology advocates for a participatory design approach, where the participants are actively involved in the design and development process. This involvement ensures that the technologies developed are not only accessible but also deeply resonate with the users' personal experiences and preferences.

Central to the methodology is the use of scaffolding strategies, which provide temporary and adjustable support to accommodate the diverse needs of individuals with intellectual disabilities. This approach facilitates meaningful participation in the design process by prompting and fading whenever needed. Improvisation is also highlighted as a key strategy, allowing for the flexible adaptation of the design process based on immediate feedback from participants. This adaptability fosters innovation and creativity in meeting the diverse needs and preferences of individuals with intellectual disabilities.

The chapter also discusses the importance of employing alternative communication methods to ensure that the voices and perspectives of individuals with intellectual disabilities are accurately captured and integrated into the design process and mentions the role of caregivers in providing insights into the participants' needs and preferences. The methodology presented in this chapter provides a comprehensive framework for involving individuals with intellectual disabilities in the participatory design of technological solutions, aiming to create accessible, meaningful, and empowering technologies that enhance their quality of life.

The papers related to the methodological studies have been published in ASSETS 2021 [277], SIGACCESS 2021 [274], and HCII 2024 [120].

1.4.4 Chapter 4

This chapter starts the second part of this doctoral dissertation, called Digital and Interactive Technologies, extending through to Chapter 6.

In this chapter, we explore a study that focuses on improving the interaction between people with intellectual disabilities and AR applications. Specifically, we examine how AR can enhance the informal learning experience of museum content. Through a series of research visits and focus groups, we aimed to understand the preferences and perceptions of individuals with intellectual disabilities regarding an AR application called AIMuseum. This application was developed to make museum visits more accessible and engaging for participants by providing 3D models of exhibits alongside labels and audio feedback.

The research findings revealed key contributions to HCI. It sheds light on the design preferences of individuals with intellectual disabilities, such as the importance of audio feedback and that highly detailed 3D models are not essential for the success of AR applications in engaging users. Additionally, the study showcased how AR can effectively support exploring new content, holding an important potential for informal learning. The involvement of participants in the design process highlighted the value of co-design practices. It demonstrated how insights from users, with unique experiences and needs can contribute to developing accessible and effective technological solutions.

Challenges encountered during the study included the complexity of designing accessible AR experiences that cater to the varied abilities and preferences of individuals with intellectual disabilities. Issues such as the difficulty in interacting with AR elements, device handling, and the accessibility of content were noted, alongside the need for careful consideration of the physical and cognitive challenges faced by the participants.

The chapter concludes with practical guidelines for the design of inclusive AR applications and suggestions for future research, aiming to further explore the integration of gamification with AR to enhance learning and engagement among people with intellectual disabilities. This research not only contributes to the academic discourse on AR and accessibility but also offers valuable insights for designers and developers looking to create more inclusive and engaging digital experiences.

The results of this work have been published in ICCHP 2020 [122] and HCII 2023 [119].

1.4.5 Chapter 5

This chapter outlined the development and evaluation of ACCESS+, an accessible application co-designed with individuals with intellectual disabilities to improve museum accessibility. It emphasizes the crucial role of communication and how technology can facilitate this process and access to cultural heritage content. The chapter describes the collaborative design process involving experts, individuals with intellectual disabilities, and partnerships with educational institutions and museums. The application, developed using the Flutter software development kit, incorporates features like customization options for text and icon sizes, light and dark modes, Text-To-Speech (TTS), and Augmentative and Alternative Communication (AAC) pictograms to enhance accessibility and User Experience (UX).

The heuristic evaluation and redesign phase involved feedback from special education experts, leading to improvements in text readability, icon intuitiveness, and settings page layout. The application underwent multiple rounds of testing with stakeholders and individuals with intellectual disabilities, focusing on usability and the effectiveness of its features. Challenges included ensuring intuitive navigation, the need for additional training for participants, and the importance of inclusive design principles.

The chapter contributes valuable insights into the co-design process, highlighting the importance of involving people with intellectual disabilities in the development of accessible technology solutions. It underscores the challenges faced in making museum content accessible to individuals with intellectual disabilities and suggests future directions for improving the application, including incorporating additional customization options. The study demonstrates the potential of accessible applications to enhance the independence and engagement of individuals with intellectual disabilities in cultural and educational contexts.

The results of this work have been published in ICCHP 2022 [275] and ECCE 2023 [246].

1.4.6 Chapter 6

This research chapter explores the integration of social robots in museums to enhance accessibility and engagement for individuals with intellectual disabilities. Museums, as centers of culture, art, and history, often pose accessibility challenges for visitors with intellectual disabilities due to complex exhibits and sensory stimuli. The study investigates how social robots, like Pepper, can act as assistive tools to overcome these barriers, providing personalized assistance and fostering engagement and social interactions.

Through workshops with participants who have intellectual disabilities, the research examines design considerations, the potential benefits, and the challenges of incorporating social robots in museum settings. Preliminary findings indicate that social robots can significantly improve the museum experience for individuals with intellectual disabilities by enhancing access to art knowledge and encouraging social interactions. However, successful integration requires addressing technological limitations, ethical concerns, and the unique needs of the target audience.

The chapter outlines the methodology, including participant selection and workshop design, and presents findings from the workshops, highlighting varying levels of engagement and interaction with the technology. It discusses the implications of these findings for designing inclusive museum experiences and suggests future research directions to further explore the benefits of social robots in educational and recreational settings for people with diverse needs.

This study is under review at ACM CHI LBW 2024.

1.4.7 Chapter 7

This chapter starts the third part of this doctoral dissertation, called Creativity and Multisensory Integration, extending through to Chapter 9.

This chapter discusses the design, implementation, and evaluation of a Multisensory Diorama (MSD) aimed at enhancing museum accessibility and engagement for individuals with intellectual disabilities. Museums, as spaces of knowledge and cultural heritage, often present barriers to accessibility for people with intellectual disabilities, primarily due to the complexity of information and a lack of inclusive interpretation. To address these challenges, the chapter outlines the development of an MSD that utilizes a multisensory approach to facilitate learning and engagement by engaging multiple senses and modes of communication. The diorama, centered around the theme of the food chain with wolves and reindeer, incorporates interactive elements such as RFID readers, LEDs, and a fan to simulate wind, offering an immersive learning experience.

The evaluation conducted in a natural history museum with 12 adults with intellectual disabilities highlighted the MSD's effectiveness in enhancing engagement and accessibility. Participants demonstrated varying degrees of interaction, with most being able to complete tasks independently or with minimal assistance. The study found that the MSD encouraged exploration, understanding, and learning, with feedback mechanisms like LEDs and sound effects aiding in conveying the correct answers in the interactive game component. Emotional responses varied, with many participants showing enthusiasm and enjoyment.

Despite its positive outcome, the study acknowledged limitations, including ambient noise affecting audio feedback and the challenge of competing stimuli in the museum environment. Future work will explore enhancements to the MSD, particularly focusing on improving multisensory feedback and audio volume to further increase accessibility and engagement. The research contributes to the field by demonstrating the potential of multisensory dioramas to make museum experiences more accessible and engaging for people with intellectual disabilities, emphasizing the importance of inclusive design in cultural and educational spaces.

The results of this work have been published in INTERACT 2023 [121].

1.4.8 Chapter 8

This chapter outlines the development and impact of "EmpowerBox", a multisensory, self-representation tool designed to enable creative self-expression among individuals with intellectual disabilities. By leveraging the principles of the maker movement, electronics, and contemporary learning methodologies, EmpowerBox facilitates holistic interaction through auditory, tactile, visual, and personal elements. This chapter provides motivation, design philosophy, and user-centric considerations to EmpowerBox empirical evaluation. It highlights the project's contributions to enhancing communication, creativity, and social interaction among participants, shedding light on the broader societal benefits of inclusive and creative collaboration.

The design of EmpowerBox is centered around accessibility and engagement, with a detailed examination of its structural design, including its multisensory features and the participatory methodology employed to engage participants in its creation. The empirical evaluation captures qualitative insights into participants' experiences, revealing the initiative's effectiveness in fostering self-expression and social interaction. The discussion section delves into the implications of these findings, emphasizing the potential of assistive technology to reshape societal perceptions and attitudes toward individuals with intellectual disabilities.

Challenges such as the need for a short learning curve, low entrance barriers, and the replicability of the technology are addressed throughout the design and implementation process. The chapter concludes by acknowledging limitations and outlining avenues for future research, reaffirming the significance of EmpowerBox in advancing the discourse surrounding assistive technology and promoting inclusivity.

The study will be submitted to ACM SIGACCESS ASSETS 2024.

1.4.9 Chapter 9

This chapter outlines an approach called "Artistic Fusion," aimed at enabling individuals with intellectual disabilities to engage in creative expression through the merge of their drawings with original museum artworks, facilitated by AI technologies. It addresses the challenges faced by individuals with intellectual disabilities in accessing conventional artistic creation and cultural engagement spaces.

By leveraging the capabilities of generative AI, the study introduces a participatory approach that combines technology and human creativity to foster inclusivity and empowerment. The methodology involved workshops with participants creating drawings that were then merged with museum artworks using AI, highlighting the process' impact on creative expression, inclusivity, empowerment, enjoyment, and engagement.

The findings reveal positive outcomes, such as increased creative perspective, emotional engagement, and a sense of ownership over the artistic creations. However, the study also acknowledges challenges such as ensuring the authenticity of AI-augmented creative processes and addressing potential biases. It proposes a framework for human-AI collaboration with roles for human curators and moderators to oversee the AI's output, ensuring it aligns with participants' intentions and is culturally sensitive. This research contributes to the discourse on the potential of AI in enhancing creative expression and inclusivity for individuals with intellectual disabilities, highlighting the importance of participatory approaches and the need for careful consideration of ethical and bias-related challenges.

The results of this work have been published in OzCHI 2023 [115].

1.4.10 Chapter 10

This chapter starts the last part of this doctoral dissertation, called Discussion and Conclusions, which also includes the final chapter.

The discussion chapter delves into designing technologies for people with intellectual disabilities, focusing on inclusive design principles and participatory methods. It highlights how involving individuals with intellectual disabilities in the design process – adapting methods, co-designing, and incorporating alternative communication methods – leads to more accessible and meaningful technological solutions. The chapter further explores the role of participatory evaluation in refining digital and interactive prototypes for museum visits, emphasizing the importance of accessible communication methods, hands-on testing, and iterative design processes to cater to the diverse needs and preferences of people with intellectual disabilities. It also examines how technology can facilitate creative and multisensory experiences, discussing the chapters that integrated sensory elements and personal storytelling to foster engagement and expression.

The dissertation also discusses the engagement of individuals with intellectual disabilities with digital and interactive technologies, noting the potential of augmented reality, accessible applications, and social robots to enhance museum experiences. It outlines the benefits and challenges of each technology, stressing the need for adaptable and flexible solutions to accommodate diverse user backgrounds and literacy levels.

The importance of effective communication in the co-design process is underscored, emphasizing the reciprocal nature of communication between researchers and participants and the valuable input from educators, support workers, and other stakeholders. The chapter acknowledges the limitations encountered during the research, such as contextual challenges and technological constraints, and suggests future directions to address these issues and expand upon the dissertation's findings. The future directions include further integrating gamification with AR technology, improving the usability and accessibility of museum applications, exploring the impact of social robots on long-term engagement, evaluating new multisensory feedback mechanisms, and assessing the broader implications of projects like EmpowerBox and Artistic Fusion on communities and societal perceptions of intellectual disabilities.

1.4.11 Chapter 11

This chapter concludes this doctoral dissertation by discussing the overarching findings and contributions to HCI, underscoring the significance of inclusivity in technology design and the potential of digital technologies in making cultural institutions more accessible and engaging for people with intellectual disabilities. This work advances our understanding of participatory design and technological inclusivity and highlights the importance of integrating individuals with intellectual disabilities into cultural and creative experiences.

1.5 Publications Overview

The following lists of publications are organized in chronological order:

1.5.1 Publications in this Doctoral Dissertation

[122] **Guedes, L.S.**, Marques, L.A., Vitório, G.: Enhancing Interaction and Accessibility in Museums and Exhibitions with Augmented Reality and Screen Readers. In: Computers Helping People with Special Needs, vol. 12376, pp. 157–163. Springer International Publishing (2020).

Abstract: Throughout the evolution of humanity, technologies have served as support for new evolutionary horizons. It is an unambiguous fact that technologies have positively influenced the masses, but they have also brought a remoteness with local cultures, often making them oblivious. Among the new technologies and forms of interaction, we have augmented reality and screen readers that allow the device to read the content. This paper presents AIMuseum. It aims to facilitate accessing and interacting with cultural environments for people with different abilities, combining the use of technologies with local museums, artworks, and exhibitions. The work was evaluated with 38 users, ranging from 16 to 41 years old, and five declared having one type of disability. They used the application and answered a questionnaire. The results showed a positive experience and improved the users' interest in the artworks and their additional information.

[117] **Guedes, L.S.**, Landoni, M.: How are We Teaching and Dealing with Accessibility? A Survey from Switzerland. DSAI 2020, Association for Computing Machinery, Online (2020).

Abstract: The need to better understand how to support and provide accessibility has increased dramatically in recent years, whether in industry or education. Higher education institutions have an essential role in raising awareness of how important accessibility is and, at the same time, can provide students with examples of good practice in building inclusive experiences. This work aims to assess the state of the art of accessibility in Switzerland, from teaching to administrative staff. Our findings show that the majority (77%) do not teach accessibility because it is not a core part of their courses and 21% declared to don't know enough to teach. 62,5% of who is teaching accessibility teach to evaluate web pages accessibility standards and heuristics and half of them help understanding technology barriers faced by people with disabilities. Likewise, our administrative staff respondents had four times more guidelines to deal with physical access than with technology enhancements. We also found out that with the COVID-19 outbreak, our instructors mainly used extra software and were more available online.

[274] **Soares Guedes, L.**: Designing Multisensory Experiences for Users with Different Reading Abilities Visiting a Museum. SIGACCESS Access. Comput. (129) (Mar 2021).

Abstract: My work explores how technology can support different forms of reading and sense-making of text and multimedia content before, during, and after a museum visit. This paper will present AIMuseum, our pilot study, and how I plan my research. My main contribution is planned to be on the design, implementation, and evaluation of tools to support reading while catering for different abilities.

[277] **Soares Guedes, L.**, Landoni, M.: Meeting Participants with Intellectual Disabilities during COVID-19 Pandemic: Challenges and Improvisation. In: The 23rd International ACM SIGACCESS Conference on Computers and Accessibility. pp. 1–4. ACM, Online (Oct 2021).

Abstract: With the COVID-19 pandemic, we all suffered from several restrictions and measures regulating interaction with one another. We had to wear masks, use hand sanitizer, have open-air meetings, feel a combination of excitement and frustration, and eventually depend on online video calls. The combinations of these additional requirements and limitations, while necessary, affected how we could involve users in the different stages of design. It has profoundly hindered our chances of meeting in person with people with temporary or permanent disabilities. In our project, involving people with intellectual disabilities in the museum context, we also had to deal with museums being closed and physical exhibitions being canceled. At the same time, guardians and caregivers often turned to a stricter interpretation of anti-COVID measures to protect people with intellectual disabilities. This paper aims to discuss these challenges and share our lessons about coping with challenging and unpredictable situations by using improvisation.

[275] **Soares Guedes, L.**, Ferrari, V., Mastrogiuseppe, M., Span, S., Landoni, M.: ACCESS+: Designing a Museum Application for People with Intellectual Disabilities. In: Computers Helping People with Special Needs. vol. 13341, pp. 425–431. Springer International Publishing, Lecco, Italy (2022).

Abstract: Inclusive solutions are essential to improve the user experience and overall accessibility. They contribute to the independence and participation of people with disabilities and can be designed for a wide variety of contexts. In this paper, we describe a design cycle from ideation to testing and redesign of ACCESS+, an accessible application to navigate through museum content focusing on people with Intellectual Disabilities (ID). We have focused on personalized and inclusive features so that users could tailor to their needs and preferences icons and font sizes, labels, and backgrounds. Also, users could make sense of the text by looking at symbols via Augmentative and Alternative Communication (AAC), and by listening to text-to-speech of full text with highlight, tone, and pitch configuration. Finally, users could provide different forms of feedback: ratings and comments. We conducted heuristic evaluations with an educator and a psychologist, both specialists in inclusive education, redesigning the interface and moving from a system to a user-friendly terminology. We also followed the specialists' suggestions and made the icons and text of the UI more accessible.

[276] **Soares Guedes, L.**, Gibson, R.C., Ellis, K., Sitbon, L., Landoni, M.: Designing with and for People with Intellectual Disabilities. In: Proceedings of the 24th International ACM SIGACCESS Conference on Computers and Accessibility. ASSETS '22, Association for Computing Machinery, Athens, Greece (2022).

Abstract: People with intellectual disabilities often experience inequalities that affect the standard of their everyday lives. Assistive technologies can help alleviate some of these inequalities, yet abandonment rates remain high. This is in part due to a lack of involvement of all stakeholders in their design and evaluation, thus resulting in outputs that do not meet this cohort's complex and heterogeneous needs. The aim of this half-day workshop is to focus on community building in a field that is relatively thin and disjointed, thereby enabling researchers to share experiences on how to design for and with people with intellectual disabilities, provide internal support, and establish new collaborations. Workshop outcomes will help to fill a gap in the available guidelines on how to include people with intellectual disabilities in research, through more accessible protocols as well as personalised and better fit-for-purpose technologies.

[119] **Guedes, L.S.**, Zanardi, I., Mastrogiuseppe, M., Span, S., Landoni, M.: "Is this Real?": Assessing the Usability and Accessibility of Augmented Reality with People with Intellectual Disabilities. In: Universal Access in Human-Computer Interaction. pp. 91–110. Springer Nature Switzerland, Copenhagen, Denmark (2023).

Abstract: This paper assesses the perception of Augmented Reality (AR) by People with Intellectual Disabilities (IDs) when using assistive technologies in preparation for a museum visit. We designed and developed an application to test how AR can provide support and is perceived in this context. We organized a user study with 20 participants with IDs, all members of the same association. Three research visits, including focus groups, enabled us to assess the memorability of the contents before introducing AR technology and collect information about users' habits and preferences. Later, we assessed users' perception of AR individually during a test session and conducted a task-oriented hands-on session. Finally, we went to the museum with our users and gathered information about their preferences and choices when using AR in situ, constantly analyzing verbal and non-verbal feedback. We describe all our findings and discuss their implications in terms of guidelines for future design.

[246] **Guedes, L. S.**, Zanardi, I., Mastrogiuseppe, M., Span, S., Landoni, M.: Co-Designing a Museum Application with People with Intellectual Disabilities: Findings and Accessible Redesign. In: Proceedings of the European Conference on Cognitive Ergonomics 2023. ECCE '23, Association for Computing Machinery, Swansea, Wales (2023).

Abstract: In order to improve the user experience and general accessibility, inclusive apps are essential. They promote independence and engagement in individuals with impairments and may be tailored for a broad range of situations. This article outlines the different steps of the co-design process to produce ACCESS+, an accessible application for navigating museum material for people with Intellectual Disabilities (ID). We conducted three research visits with 20 participants to understand their needs and collect requirements. Our qualitative approach aims to (i) understand the overall experience with an existing museum website and application; (ii) gather the understanding of specific UI elements; and (iii) assess the overall UX provided by the new app, including the challenges with specific features and the touch-based interaction. We concentrated on customized and inclusive features, allowing users to adapt icon and text sizes, backgrounds, labels, and voices to their own requirements and preferences. Users also made sense of the content by looking at symbols using Augmentative and Alternative Communication (AAC) and listening to full-text text-to-speech with personalized tone, pitch, and highlight settings. Participants shared their thoughts, helping us to improve the accessibility of each choice. Together with technology experts, a psychologist, a museum professional, and two educators, they contributed invaluable insights, enabling this research to give helpful information for future application design.

[121] **Guedes, L.S.**, Zanardi, I., Span, S., Landoni, M.: Multisensory Diorama: Enhancing Accessibility and Engagement in Museums. In: Human-Computer Interaction – INTERACT 2023, vol. 14143, pp. 628–637. Springer Nature Switzerland, York, UK (2023).

Abstract: This paper describes the design and evaluation of a Multisensory Diorama (MSD) intended as a tool to provide an alternative learning environment for people with intellectual disabilities (ID) in museums. The MSD is designed to be interactive, engaging, and accessible to accommodate the specificities of participants with ID, and to help contextualize and consolidate previous knowledge. The MSD is a portable box with RFID readers, LEDs, a fan, a photoresistor, a button, an Arduino Uno, an MP3 shield, a speaker, and an external battery. The MSD offers two different

ways of engagement and interaction via exploration and gamification: visitors can explore the augmented landscape and play a matching game that reinforces their knowledge of the food chain in the forest. In a formative evaluation approach focusing on the accessibility and engagement with the MSD, a study was conducted with 12 adults with ID, who provided valuable feedback to improve the design and make necessary adjustments for future implementations. The MSD proved to be a successful tool for engaging visitors and reinforcing their understanding of the food chain in an interactive and accessible way.

[115] **Guedes, L.S.**, Balasuriya, S.S., Sitbon, L., Landoni, M.: Artistic Fusion: Exploring the potential of AI-Generated Artwork in Enabling Creative Expression with People with Intellectual Disabilities. In: Proceedings of the 35th Australian Conference on Human-Computer Interaction. OzCHI '23, Association for Computing Machinery, New York, NY, USA (2024).

Abstract: This paper explores the potential of AI-generated artwork to facilitate creative expression for individuals with intellectual disabilities. We present an inclusive approach called "Artistic Fusion", which combines original museum artwork with drawings contributed by participants with intellectual disabilities, leveraging the Midjourney platform. By blending these distinct artistic styles, we aim to empower individuals with intellectual disabilities to engage in artistic creation and foster inclusivity within museum spaces. We explore specific strategies for mitigating biases in AI-generated content and articulate the technical nuances of the Artistic Fusion process. We highlight the possible benefits, challenges, and ethical considerations associated with deploying AI in this context through a user-centred design approach and iterative feedback cycle.

[120] **Guedes, L.S.**, Zanardi, I., Mastrogiuseppe, M., Span, S., Landoni, M.: Scaffolding for Inclusive Co-design: Supporting People with Cognitive and Learning Disabilities. In: Universal access in human-computer interaction. Springer Nature Switzerland, Washington, DC, United States (2024)

Abstract: This paper presents a framework for integrating scaffolding in co-design sessions with people with cognitive and learning disabilities. While scaffolding has been recognized for enhancing participant engagement in co-design, its application lacks standardization. Our study pursues three primary objectives: (1) Present two case studies involving an Augmented Reality application and the ACCESS+ museum application, highlighting specific user needs; (2) Adapt the concept of scaffolding to support the informal learning needed to interact with technology while having an active role in co-design (3) Discuss how to revisit collaborative design to become more accessible and inclusive as to empower people with cognitive and learning disabilities. Through a methodical approach of task subdivision, prompt initiation, assessment of understanding, support through prompting and fading, and repetition if needed, our framework demonstrates how tailored scaffolding can effectively engage participants, emphasizing the importance of integrating diverse perspectives in technology development.

1.5.2 Additional Publications and Contributions

These additional papers were published or presented in conferences or workshops during the doctoral studies. Although these papers were not incorporated into the doctoral dissertation to maintain its coherency, they played a significant role in refining my academic abilities.

[294] Valguarnera, S., **Guedes, L.S.**: Two in a Pod: Promoting Sustainability and Healthy Eating in Children through Smart Gardening. In: Proceedings of the 2020 ACM Interaction Design and Children Conference: Extended Abstracts. pp. 241–246. IDC '20, Association for Computing Machinery, Online (2020).

[118] **Guedes, L.S.**, Ribeiro, C.C.A., Ounkhir, S.: How Can We Improve the Interaction of Older Users with Devices? DSAI 2020, Association for Computing Machinery, Online (2020).

[316] Willi, P., **Soares Guedes, L.**, Landoni, M.: A Study into Accessibility and Usability of Automated Teller Machines for Inclusiveness. In: HCI International 2021-Late Breaking Papers: Cognition, Inclusion, Learning, and Culture: 23rd HCI International Conference, HCII 2021, Virtual Event, July 24–29, 2021, Proceedings 23. pp. 330–342. Springer, Online (2021).

[185] Mastrogiuseppe, M., **Guedes, L.S.**, Span, S., Clementi, P., Landoni, M.: Reconceptualizing Inclusion in Museum Spaces: a Multidisciplinary Framework. In: ICERI2021 Proceedings. pp. 7225–7233. IATED, Online (2021).

[186] Mastrogiuseppe, M., **Soares Guedes, L.**, Landoni, M., Span, S., Bortolotti, E.: Technology Use and Familiarity as an Indicator of Its Adoption in Museum by People with Intellectual Disabilities. Studies in Health Technology and Informatics 297, 400–407 (2022).

[286] Szlavi, A., S. **Guedes, L.**: Gender Inclusive Design in Technology: Case Studies and Guidelines. In: Marcus, A., Rosenzweig, E., Soares, M.M. (eds.) Design, User Experience, and Usability, vol. 14030, pp. 343–354. Springer Nature Switzerland, Copenhagen, Denmark (2023).

[242] Moreira da Rosa, D., **Guedes, L.S.**, Landoni, M., Silveira, M.: Human Languages in HCI: Beyond User Interface Localization. In: Kurosu, M., Hashizume, A., Marcus, A., Rosenzweig, E., Soares, M.M., Harris, D., Li, W.C., Schmorrow, D.D., Fidopiastis, C.M., Rau, P.L.P. (eds.) HCI International 2023 – Late Breaking Papers. pp. 564–574. Springer Nature Switzerland, Cham (2023).

[243] da Rosa, D.M., Silveira, M., **Guedes, L.S.**, Landoni, M.: Patterns of Reading Assistance for Software Users with Varying Reading Skills. In: Proceedings of the 28th European Conference on Pattern Languages of Programs (EuroPLoP '23). Association for Computing Machinery, New York, NY, USA, Article 34, 1–12 (2024).

[116] **Guedes, L.S.**, Johnstone, J., Ellis, K., Landoni, M.: Creative Technologies in Action: Empowering Individuals with Intellectual Disabilities. In: Computers Helping People with Special Needs. Springer International Publishing, Linz, Austria (2024).

2

Literature Review

This chapter offers a comprehensive overview of the literature at the intersection of individuals with intellectual disabilities, HCI, and accessibility. It explores key theoretical frameworks and methodological approaches that have shaped the field of accessibility research and HCI as it pertains to people with intellectual disabilities.

In the process of writing this doctoral dissertation, I conducted an extensive review of literature across a broad spectrum of databases, venues, and journals. It became clear from this review that the body of literature specifically addressing the work with people with intellectual disabilities within HCI and even within accessibility research is notably limited, as also highlighted in literature [178].

The subsequent sections of this chapter will delve into a more detailed exploration of people with disabilities and the design processes that include them, the role of museums and informal learning environments in accessibility, and will discuss in detail the specific problems that this doctoral dissertation focuses on. This includes examining the current state of research, identifying gaps, and highlighting innovative practices and solutions that contribute to the inclusion and empowerment of individuals with intellectual disabilities within the digital world.

2.1 People with Intellectual Disabilities

The World Health Organization defines intellectual disabilities as a significant reduction in the ability to understand new or complex information, learn new skills, and have a notable impact on daily life, beginning before adulthood [315]. Intellectual disability stands as a neurodevelopmental disorder characterized by cognitive and adaptive functioning deficits [11]. Intellectual disabilities originate before the age of eighteen [258] and range in severity, with some individuals requiring minimal support for relatively independent living, whereas others necessitate extensive, ongoing assistance [11, 221]. It is important to acknowledge that the terminology and classifications vary internationally [304].

The severity of intellectual disabilities can vary greatly, with some individuals experiencing mild challenges and being able to live relatively independently with the right support, while others may require significant and daily assistance [259] [221]. Support is crucial in both formal and informal education settings, as conventional learning strategies may not be suitable for people with intellectual disabilities without specific accommodations or modifications [155, 281]. This is partly due to limitations in cognitive functions, which may encompass challenges with abstract concepts, memory, problem-solving, planning, reasoning, and generalization [11, 81, 133, 312]. Effective support must be tailored to the individual's specific needs and environmental interactions [216].

Beyond cognitive abilities, social and practical domains play a crucial role. The social domain covers empathy, interpersonal skills, and the ability to form friendships, while the practical domain involves self-management in education, work, and leisure [288]. People with the same medical diagnosis can exhibit a high degree of variability in characteristics, influenced by differences in cognitive skills like language, memory, attention, and visual-perceptual abilities [75, 298], however, while some cognitive functions might be impaired, others can remain unaffected or even contribute to talents [192]. This variability affects personality and social-practical environmental adaptation. Individuals with intellectual disabilities may find it harder to engage with others which can increase the challenges in learning and carrying out everyday tasks necessary for living independently [11, 81, 221].

In recent years, worldwide emphasis has been placed on improving the quality of life of people with intellectual disabilities [326]. This includes aspects such as the introduction of disability-focused government policies and laws (e.g [20, 84, 151]); the abolishment of segregated institutions, like healthcare and education, in favor of public inclusion [293]; and the wider (yet not quite sufficient) availability of assistive technologies and services [44]. In terms of the latter, Boot et al. [44] suggest that an increased focus on the development of assistive products for and with people with intellectual disability may accelerate the advancement of their health [102] [223] [224] and the realization of their basic human rights.

This doctoral dissertation focuses on the strengths and abilities of people with intellectual disabilities instead of relying on their disabilities. Contemporary research emphasizes a paradigm shift from designing for people with disabilities to engaging them as equal partners in the design and research process [94, 181]. This shift necessitates reevaluating our engagement strategies, interaction methods, and terminologies when referring to research participants with disabilities. The relevance of assistive technologies and applications is paramount in enabling the inclusion of people with intellectual disabilities in societal frameworks, promoting their independence and well-being [44]. The design processes often overlook the inclusion of individuals with intellectual disabilities in the early stages, resulting in high abandonment rates for assistive technologies, reported to be over 50% [229]. Accessible design can help everyone, not just those with a disability [183]. Nevertheless, existing technical solutions [182] [131] [97] only partially cover the needs of users with intellectual disabilities [78].

2.2 Designing with People with Intellectual Disabilities

Developing Information and Communication Technology (ICT) that meets the needs and abilities of people with intellectual disabilities requires a shift from standard design. Their direct involvement in the design and evaluation processes is needed to ensure that the resulting products are not only accessible but also meaningful to their daily lives [33, 39, 68, 87, 282], however, traditional co-design and user-centered approaches frequently rely on a standardized set of participant skills that may not accurately reflect the ones used by the participants to express themselves or conceptualize their experiences, or for which participation may be adapted as needed [132].

Researchers may not feel confident enough to involve persons with intellectual disabilities in the co-design process without instructions and assurance from the community [271], this may also be due to their inability to relate to the participants' experiences [132]. By reviewing prior literature and participating in expert-led workshops, Hendriks et al. [132] investigated the potential development of a methodological approach specifically intended to increase the engagement of people with intellectual disabilities in co-design. However, they realized that a single strategy did not adequately account for the variety of life experiences that people with intellectual disabilities have, leading to advocacy for more individualized and adaptive design techniques [132], emphasizing the need to disseminate the lessons learned and adjustments needed while developing research methods in order to create a body of research that may enhance the future of accessibility.

2.2.1 Advancing HCI for Inclusion

One innovative strategy proposed to address these challenges involves leveraging the expertise of "experts" in intellectual disabilities to co-design workshops that are more accessible and engaging for participants [108]. Such approaches, including the use of scaffolding, aim to provide temporary support to help participants achieve goals that might otherwise be unattainable, gradually removing these supports as they become unnecessary [324]. This metaphorical scaffolding facilitates a systematic interaction between the participants and a more knowledgeable other, whether it be an educator, researcher, or caretaker, underscoring the collaborative nature of the co-design process.

Despite these advancements, there is a continued need to refine and expand the methodologies and approaches used in co-design to better accommodate the unique perspectives and abilities of individuals with intellectual disabilities. The HCI community has therefore begun to explore the co-design of technologies to support people in navigating the web [13, 25, 241], learning early and continuous life skills [14, 15, 49, 163, 272], utilizing public transport [273], and communicating medical symptoms [107, 108]. Nevertheless, there is still much to be done to reduce the experience of everyday inequalities.

2.2.2 Communication

Communicating is central to participation in research, or in design, and people with intellectual disability may choose to communicate in a range of modalities, which should be equitably recognized. Researchers need to carefully consider representing the views of all their participants; some participants may be able to present in-depth feedback, while others may only pronounce basic sentences, rely on signing languages such as Makaton [179], or provide yes/no responses. In addition, some participants are likely to make use of AAC to share their views, which can range from physical, picture-based artifacts, such as Talking Mats [170], to intricate text-to-speech technologies.

Researchers also need to carefully consider the context in which participants with intellectual disability are sharing their views, as some people may not be comfortable expressing themselves as part of a group, or towards people who are not familiar to them [189]. Communication may be mediated by people who know participants well, as they can support the condition of participation, and support the researcher in correctly capturing the meaning of what participants chose to share. It is, however, unclear how alternative forms of expression, including mediated communication [299], should make their way into the structure of research data collection.

2.2.3 The Role of People with Intellectual Disabilities and Their Caregivers

Due to the shift in emphasis towards co-design [33, 39], people's role in research is changing from largely participant-based (or even as a bystander) to a more prominent position where they are actively involved in leading activities and making decisions. Nevertheless, much of the discussion surrounding the inclusion of people with intellectual disability focuses on the former approach. Consequently, we will encourage participants to also share experiences that will support others in working with people with intellectual disability as part of a steering committee, or as fully-fledged co-researchers.

In addition, there is a continuing debate on the role caregivers should have in research involving people they support. On one side, researchers suggest that the goals and motivations of people with intellectual disability differ significantly from those of their carers, meaning the contributions of paid and non-paid caregivers should be limited to support only [132]. In contrast, other researchers have found caregivers to be knowledgeable about the experiences and needs of people they support, and have therefore advocated direct involvement within studies [76, 271, 273]. As such, there is an opportunity to add further empirical evidence to this debate.

2.2.4 Design and Evaluation Methods

As highlighted, traditional human-computer interaction techniques often rely on a unique and generic skill set that may not reflect the diverse abilities of individual participants with intellectual disabilities [68, 132]. For example, speech is typically at the center of co-design methodologies, yet participants may find it difficult to present their views on complex or unfamiliar topics using their voice or natural language, or to people they do not know and trust [76, 77, 132, 185, 229, 273]. Hands-on tasks often expect participants to master fine motor skills, while verbal instruction or the operation of intricate technologies relies on participants having a good short-term memory [297]. Furthermore, co-design activities, such as analysis and ideation, tend to rely on participants' higher-order cognitive skills (e.g. abstraction and creativity) [42, 76, 77, 132] which may not be how participants prefer to evaluate the potential use of novel technologies. Finally, common evaluation methods such as Likert Scales are open to response bias, with participants typically selecting the most positive options [127] and requiring appropriate scaffolding.

2.3 Co-design, Scaffolding and Improvisation

2.3.1 The Scaffolding Process

Over the past two decades, the concept of scaffolding has become a key metaphor in psychology and education, initially representing how caregivers such as teachers assist in a child's learning and development. This idea, first elaborated by Wood, Bruner, and Ross [324], draws heavily from Vygotsky's concept of the zone of proximal development (ZPD) [303]. ZPD represents the range where learners are capable only with support from someone with more knowledge or expertise. An enriched version of the metaphor has been created over the years, with applications to the study of parent-child and teacher-student interactions involving learners with learning disabilities (e.g. [284]).

In a comprehensive review of the field, van de Pol et al. [226] scrutinizes the most important areas of scaffolding:

1. **Contingency**: This involves the caregiver adjusting the level of assistance according to the learner's competence. Strategies the caregiver could use to personalize the learner's assistance include actions that can be executed simultaneously:
    - **Physical prompts**: Giving physical help, such as accompanying the learner's action with body movements.
    - **Gestural prompts**: Using gestures like pointing or nodding.
    - **Verbal prompts**: Providing verbal feedback, hints, or questions.
2. **Fading**: The gradual withdrawal of support as the learner gains more and more competence [69]. For example, reducing physical assistance from guiding a finger to less direct forms of help, like verbal prompts.
3. **Transfer of Responsibility**: As fading increases, the learner's responsibility to independently perform the task increases and evolves with the ultimate aim of achieving the action spontaneously, without the need for assistance.

Throughout the entire process, a pivotal role is played by evaluation strategies [227]. Effective support can be initiated and gradually ended based on the learner's responses to the received assistance. The explicit control of the analysis can help both parties to develop inter-subjectivity [245].

2.3.2 From Scaffolding to Co-design

Scaffolding has been increasingly used in recent years to explore social support in technology-mediated learning environments [332][10], as it improves learning and self-regulation while co-designing [332]. In this study, we refer to co-design as a verb to indicate the act of incorporating community members in the design process [331] to ensure the rights of individuals with intellectual disabilities [210].

Co-design developed from the long tradition of Participatory Design, and it incorporates a variety of methods and tools aimed at giving participants power over the design process. Because of the focus on user engagement, different approaches target different user groups, including people with disabilities [237]. When involving individuals with intellectual disabilities, it is crucial to have multiple means of eliciting needs while also keeping attention and engagement [108]. As an example, Co-Design Beyond Words (CDBW) aims to facilitate various forms of expression that do not depend on verbal communication, which amounts to a reflection-in-action process [318]. To enhance user engagement and bridge the knowledge gap between researchers and participants, one approach is to involve users with concrete objects [108] [318] or prototypes that can aid in increasing their involvement [39] [282] [325] [121].

In this context, scaffolding has been used more or less implicitly to aid sessions. In HCI, Active Support (AS) investigates how varying degrees of engagement might be allowed through graded assistance, with fading serving as the key to reducing support [39]. This is particularly important when taking into account the different participation levels that might be attained throughout a session [282]. Regarding engagement with prototypes, [325] emphasizes the necessity of stimulating conversation to extract their viewpoints. To facilitate requirement elicitation, tools and materials themselves can act as a scaffold [135] [200] [318] and encourage engagement [95]. Their use also requires building or removing scaffolds *in situ* to accommodate the participant's experience [180]. Most broadly, scaffolding is used to structure not only the tasks but also the session itself [35], social relationships [318][329], collaboration between participants [295][309], and the environment [318].

2.3.3 Improvisation and Adaptability on Co-Design

The literature describes methods to deal with improvisation and co-design. Some works have as target groups children, older people, and people with disabilities. Even if the focus is on different groups of people with permanent or temporary disabilities and needs, we report experiences showing how to design in critical situations by taking advantage of improvisation. Gerber argues that improvisation can build perspectives and experiences that are crucial for designers, such as learning through error, creative collaboration, fostering innovation, supporting spontaneity, and presenting ideas [105]. Considering the iterative nature of design research and its impact on shifting research directions, the concept of Research through Design [334] contributes to reframing problems within the HCI domain. This concept can significantly shape co-design with people with intellectual disabilities by emphasizing the importance of adaptability and responsiveness to the diverse needs and feedback of participants. Consequently, research activities become more flexible and open-ended, allowing for continuous refinement and adjustment based on ongoing engagement with participants. Engagement can have different effects on different modalities, as synchronous online co-design sessions add layers of complexity and uncertainty to collaboration [167]. The work published by Lee et al. introduces a model to co-design with youth synchronously and presents improvisation as a method of inquiry for co-design sessions. Additionally, by analyzing video recordings of co-design groups, Chinn and Pelletier [65] explored how the tensions between co-designers and experts' different abilities were manifested, contributing to the way co-design is conducted and improvisation is applied.

2.4 Museums, Informal Learning and Accessibility

2.4.1 Museums and Informal Learning: The Role of Accessibility

Museums are regarded as informal learning environments [162]. Informal learning is defined as learning in a socially collaborative context where the learner can choose what and how to learn, with activities focused on meaningful tasks that do not require assessment or have a predetermined goal [55, 239]. Museum participation, in fact, is voluntary, since visitors choose based on their interests [162], but also because visitors can plan their tour, creating a personal agenda [91]. This way, the learning process is connected to self-determination, which is critical for achieving positive learning outcomes [114, 314] and ensuring an improved quality of life and life satisfaction for people with intellectual disabilities [314]. Wakatsuki et al. [306] aimed to identify how museums might assist visitors in enjoying a more educational and pleasant experience. The most desired quality, they discovered, was that staff members be understanding and educated in proper communication and support techniques. Furthermore, museums can stimulate involvement in cultural life and promote inclusion [233, 251]. As a result, accessibility must be considered to let people with disabilities participate in museum experiences and the resulting informal learning [57, 233]. With this goal in mind, technologies can help to achieve accessibility [57, 260] through inclusive design that is based on real-world testing and application [260], calling for the involvement of the Human-Computer Interaction community.

2.4.2 Accessible Museums for People with Intellectual Disabilities

Museums offer great resources for people with intellectual disabilities, offering opportunities for learning and enrichment. Moreover, they are an essential part of the community and cultural life of a person [233, 252], and as such, museums need to consider the needs of visitors with intellectual disabilities when designing exhibits and experiences. An inclusive museum has to provide accessibility on the *architectural, digital and sensory* aspects [43]. This can include providing clear signage, accessible seating, and alternative formats for exhibit content. For the latter, technology can play an important role in making museums more accessible and engaging for people with intellectual disabilities. By using technology to create inclusive experiences, museums can help ensure that visitors with intellectual disabilities feel welcome and included. This can encourage greater participation and engagement from visitors with intellectual disabilities, leading to a more enriching and rewarding experience for everyone.

To date, inclusive technology in museums has primarily focused on people with visual impairments, with a focus on navigation and auditory information solutions [17, 60, 106, 176, 296, 308]. Several studies have investigated solutions for this group, followed by solutions for people with hearing impairments [88] and wheelchair users [72]. However, while existing technologies have been adapted to cater to the needs of visitors with disabilities, these efforts have largely overlooked people with intellectual disabilities. Current approaches aim to improve the basic accessibility and overall experience in museums but fail to address the needs of this important group.

2.5 Accessible Solutions

2.5.1 Designing for Inclusion

Designing inclusive technology is crucial to promote independence for individuals with intellectual disabilities, as technology offers a flexible environment that can take multiple abilities into account, enabling inclusive design that benefits everyone. Additionally, in today's society, digital accessibility is essential to ensure equal participation in all aspects of life, as technology has a significant impact on our daily routines. Assistive technology, which is an umbrella term for any technology adapted or specially designed for improving the life of a person with a disability [216], can enable people with intellectual disabilities to live independently and actively participate in social and cultural life [217]. These accessible solutions are an important area of study that includes as well people with intellectual disabilities as users, both in work-related context [199] and educational context [83].

The first step to ensuring inclusion is to involve people with intellectual disabilities in the design process. Their participation is critical to gather valuable insights: by involving them, designers and researchers can understand their needs and consequently create solutions that can address them. Their level of participation can be viewed as a continuum based on the design stage and the abilities of the participants [57]. They can be co-researchers who consciously and directly help to design the solution; feedback givers who actively suggest improvements; testing users who are observed while trying the solutions; or they can be substituted by proxies or experts who can analyze the solution on their behalf [57]. While including people with intellectual disabilities as co-designers may be difficult, their participation is still valuable, even if it is limited, because they can provide feedback even if they do not fully understand the technology [39].

The second step is to make technology accessible. Accessibility refers to the measure of a solution's availability and usability regardless of a person's abilities. The Web Content Accessibility Guidelines (WCAG) and Cognitive and Learning Disabilities Accessibility Task Force (COGA), developed by the World Wide Web Consortium (W3C), provide a set of requirements for designing and evaluating the accessibility of digital solutions [305]. In particular, WCAG is structured around four tenets: both content and User Interface (UI) of an application should be *perceivable*, *navigable*, *understandable*, and *robust*.

2.5.2 Enhancing Communication and Reading

Enhancing communication and reading for people with intellectual disabilities involves a multifaceted approach that integrates various techniques and technologies. Starting with the basics, picture identification is a common method used to help individuals recognize words and enhance reading skills, as explored by Browder et al. [48]. Additionally, phonetic adjustments can improve word identification, supporting legibility [89]. Considering readability and comprehension, [51] argues how understanding real-life situations aid individuals in navigating their personal experiences.

In the realm of digital accessibility, the inclusive research concept [71] and the automatic cognitive assistance in web browsing [205] illustrate advancements in making digital content accessible. Similarly, adaptive user interfaces within the Easy Reading framework [134] have shown potential to enhance the online experience for users with cognitive disabilities. Furthering this digital integration, the TriAccess system proposed by Chen et al. [64], which provides physical, sensory, and cognitive support, exemplifies a comprehensive approach to support diverse readers, including those with cognitive impairments. The ALLT system discussed by Attarwala [19] extends this support into social reading environments, facilitating shared reading experiences that can be particularly beneficial in family settings.

The importance of Augmentative and Alternative Communication (AAC) systems is underscored by Sobel et al. [278], who investigate AAC's design implications, and by Sutherland's [285] survey in New Zealand, which confirmed the significant need for these systems among adults with intellectual disabilities. This is further developed through interactive designs like the TalkingBox [40], which integrates tangible technology with graphic symbols to promote engagement through memory-matching games. Lastly, the potential of multisensory storytelling in supporting cognitive functions is exemplified by Matos et al. [188], showing improvement in memory retention through diverse sensory inputs. This concept is applied in broader contexts such as virtual reality and participatory design by Gelsomini [104] and Robb [238], focusing on children with special needs, to create more immersive and accessible learning environments.

2.6 Augmented Reality

AR has a unique ability to create immersive and interactive experiences that overlap virtual information with the real world [8]. AR's ease of connectivity [266] enhances learning and exploration, making it ideal for informal learning settings [235]. In this section, the literature review focuses on AR for learning, for museums, and on designing accessible AR.

2.6.1 AR for learning

AR is a rapidly growing field that is changing how people interact with the virtual and real world. It superimposes virtual information onto the real world, creating an immersive and interactive experience [8]. With the increasing availability of devices, AR is quickly gaining popularity [101] and has the potential to revolutionize a wide range of industries, including education [8]. In the field of education, AR has the potential to enhance the learning experience [63, 257]. Several studies have explored the benefits of AR in education and the results are positive [8, 100]. AR has been shown to increase motivation [279] and engagement [143] among students, as it presents virtual content in a realistic setting that makes learning more interactive and enjoyable. Because of this, its application has the potential to support individuals with intellectual disabilities in their learning and development [27]. As previously stated, individuals with intellectual disabilities may encounter obstacles with traditional learning methods [155, 281], and with AR they are able to experience virtual content in a way that is more accessible and engaging [54, 157]. This can increase their motivation and engagement in learning, and reduce their dependence on caregivers [145]. With AR, individuals with intellectual disabilities are able to independently explore educational material, allowing them to take control of their own learning process and develop new skills [145], making this technology suitable for informal learning contexts. Indeed, AR interventions seem to be the most effective when conducted in informal learning settings as part of informal activities [100].

In recent years, various AR solutions for individuals with disabilities, particularly visually impaired individuals, have been developed. These can aid in developing important life skills such as ironing, making the bed [47], using ATMs [153], shopping for groceries [333], and even playing games [22]. Additionally, AR has been proven effective in improving literacy [9, 190] and numeracy skills [58, 157, 248], as well as in improving learning outcomes in other school subjects, such as scientific knowledge [235]. AR applications can be standalone or enhanced by incorporating other sensory stimuli, such as tactile [212] and olfactory feedback [234].

2.6.2 Accessible AR in museums

Accessible AR has been widely adopted in museums because of its *authenticity*, referring to its promise of meaningful experiences, *multisensory affordances*, which refer to its ability to provide multiple sensory modalities, *connectivity*, alluding to its ability to connect quickly with and within an environment, and *exploration* [266]. Some AR applications specifically designed for visually impaired individuals enhance their museum experience by providing spoken descriptions of artworks [6]. The integration of AR technology not only makes the descriptions more interactive but also empowers visually impaired visitors to experience the art independently. In some cases, AR is combined with physical objects to offer a multi-sensory experience, further enhancing the overall experience [212, 234]. Hard-of-hearing individuals can also benefit from AR application, which fosters a more direct and authentic interaction with the artwork, promoting independent exploration and enjoyment of cultural heritage [29]. For individuals with intellectual disabilities, museum AR applications provide assisted navigation [92] and a more interactive approach to cultural heritage, allowing for a more direct experience [283].

2.6.3 Designing accessible AR

The development of accessible and inclusive AR is essential for ensuring that everyone, regardless of their abilities, can enjoy the benefits that AR has to offer. One of the key considerations in creating accessible AR content is to follow accessibility guidelines such as the WCAG [305]. These guidelines provide a framework for ensuring that digital content is designed in a way that is usable by as many people as possible, including those with disabilities. Indeed, accessibility features play a crucial role in learning and comprehension, both for individuals with disabilities and for everyone else. Visual accessibility, for example, can be achieved through the use of easy-to-read texts [90], which use simple language and short sentences, or Augmentative and Alternative Communication (AAC) [37] that uses pictograms. Auditory feedback, such as text-to-speech (TTS) technology [52], can also be used to make AR content more accessible. TTS technology is particularly valuable for non-literate individuals with intellectual disabilities, but further research is needed to fully understand its impact on reading proficiency and comprehension [274].

Aside from following accessibility guidelines, it is critical to include people with disabilities in the design process in order to create truly accessible and inclusive AR content. Ongoing research is exploring methods for working and co-designing with individuals with intellectual disabilities through focus groups, co-design, and active support [39, 68]. Participatory design helps to ensure that AR technology is designed with the needs of people with disabilities in mind and that it can be used to improve their learning and development [273]. However, when developing AR applications, the majority of researchers still involve people with intellectual disabilities as passive subjects [266], posing doubts about those application's efficacy.

2.7 Social Robots

2.7.1 Social Robots and their Impact on Intellectual Disabilities

Whilst significant research has explored the use of robots by children and teenagers, particularly those with autism, and elderly people with dementia [247, 269], there has been limited focus on how adults with intellectual disabilities might benefit from this technology. The studies involving this demographic often lack direct interaction with robots, relying instead on pictures and concepts [317, 323]. This approach can inadvertently enforce negative views and present barriers to further research. In contrast, direct interaction with social robots tends to generate more positive attitudes [86]. The physical embodiment of a robot, as opposed to virtual agents, increases the sense of social presence and is generally preferred by people [80, 150, 169, 270].

Engagement in learning activities is crucial, particularly for individuals with intellectual disabilities. Incorporating robots in these activities has shown to increase engagement [26, 34, 129]. However, while these studies highlight potential benefits, the direct impact on knowledge acquisition and long-term outcomes remains under-explored. The research by Beccaluva et al. [34] reveals that robots consistently engage participants with intellectual disabilities, which is vital for effective learning processes. Various methods have been employed to measure engagement, including observational metrics, analysis of verbal and non-verbal responses, self-report measures, and task performance metrics. Each method offers unique insights into the engagement and learning processes in robot-assisted support for individuals with intellectual disabilities [12].

To expand the multi-modal communication abilities of social robots, they can utilize embedded [198] or external [301, 322] tablet technologies. These tablets allow them to display text, symbols, and images and to receive user input, thereby enhancing their capacity for interactive and engaging dialogues [7].

The flexible range of modalities offered by social robots, such as tablets, speech, vision, or touch sensors, allows individuals to engage in ways that best suit their communication abilities and preferences. This anthropomorphic and social aspect of robots may increase their acceptance as community members and motivate users to continue interacting with them [32, 206].

2.7.2 Technology for Engagement and Inclusivity

More broadly, technology can empower people with disabilities, promoting social inclusion, participation, and self-determination [56, 313]. However, the social stigma associated with specialized assistive devices can be a barrier, as they might imply helplessness or inability to use mainstream technologies [268]. To address this, universal design principles in mainstream technologies, like smartphones, are blurring the lines between assistive and mainstream devices, promoting inclusivity [73, 313].

Despite these advancements, a notable gap persists in research, particularly in the context of museums [57]. This gap impacts the accessibility of cultural spaces and the technology employed within them. Hellou et al. [130] identified five crucial features for social robots in museums: social navigation, perception, speech, gestures, and behavior generation. While previous studies have focused on exploring augmented reality [119] and dioramas [121] in museums for visitors with intellectual disabilities, the exploration of social robots in this context remains under-explored. Therefore, there is a compelling need for further research to understand the potential and implications of social robots in enhancing museum experiences for people with intellectual disabilities.

2.8 Multisensory Experiences

2.8.1 Multisensory Experiences for Accessibility and Learning

In recent efforts to provide inclusive interactive technologies, the multisensory approach has received special attention [161]. Multisensoriality for people with disabilities has been employed with different applications, ranging from multisensory smart objects [50, 149, 213] to multisensory environments [96, 166, 220], and with different goals, such as relaxation [136], communication [213], and learning [50]. Indeed, multiple sensory modalities can benefit learning [265] as they present information that can be more accessible according to the preferences of the learner [202], enhancing learning opportunities for everyone

[85]. Multisensory experiences can also be found in museums, where multisensory technology creates immersive experiences and empowers imagination [139]. Regarding accessibility, multisensory solutions typically focus on visual impairments [172], as visual information constitutes the majority of museums' content [139], and visitors with intellectual disabilities received less attention in HCI technologies.

2.8.2 Technological Enhancements in Museum Dioramas

When it comes to enhancing learning experiences, natural history museums frequently employ dioramas [144, 292], which are "three-dimensional depictions of animal-landscape sceneries that include real or artificial models of animals in combination with background paintings and natural or artificial requisites" [152]. Because of their educational value [291], their potential in relation to HCI has been investigated to understand how technology could enhance dioramas. Although museums are the most common setting for digital dioramas, there are also applications set in schools to provide hands-on experience with science concepts [70, 98, 236]. Aside from traditional physical ones [70, 236, 249], there are virtual reality dioramas [98, 208, 209], augmented reality dioramas [126, 165, 209], and mixed reality dioramas [128]. Interaction is typically achieved through external controllers [98, 128, 208, 209, 236, 249], with only a few opting for physical interaction [70, 126, 165], highlighting a lack of multimodality. Similarly, there is a lack of multisensoriality. The sensory output of digital dioramas is primarily visual, with occasional incorporation of auditory feedback [70, 126, 249] and even less frequent incorporation of haptic output [249]. The latter is the only one designed specifically for people with disabilities, explicitly those with visual impairment. The target users of digital dioramas are not always specified because they are appealing to a wide range of people [128, 208, 209], but when the design is specific to a defined population, targets are usually children [70, 98, 126, 165].

2.9 Electronic Making and Creative Expression

2.9.1 Storytelling as an inclusive practice of self-discovery

People who are perceived to be different have historically been marginalized (e.g., [30, 158]. Along with its moral stance, the need to fight this phenomenon has advocated first for social integration, and then social inclusion as a human right [210, 300]. As stressed by the emphasis placed on the social sphere, inclusion is a complex interpersonal process [193] shaped not only by countries' policies and people's attitudes but also by personal social skills [168, 195, 321]. Together with the challenge posed by ableism [79, 99], there is the issue of accessibility: inclusion necessitates paying attention to the diversity of abilities and strengths of people with intellectual disabilities, rather than simply accepting it as a personal principle. It is not surprising, then, that people with intellectual disabilities have lower levels of social inclusion than those without [195, 196], despite the fact that social inclusion is critical to their well-being and quality of life [21, 168, 321].

Social inclusion, as an interpersonal process, is then linked to our socialization experience. People with intellectual disabilities want (and should be able) to belong and feel connected, and by participating in the socialization cycle, they can gain social competence, experience belonging, satisfaction, and connection, which in turn expand their circle of friends and provide more opportunities to engage in socialization [321]. Sharing, and particularly sharing our story, is one way to forge this connection. Meininger [193] proposed that life stories have the ability to connect and thus provide the foundation for social inclusion. For the purposes of this investigation, we will refer to two major connections: the connection to oneself and the connection to another. Stories connect the storyteller to their own life, by threading a line between *ourselves* and what *makes us* ourselves. Stories provide meanings that stem from what we *were* to give us a glimpse of what we *could be*, of "the unknown future", and those meanings are intended to be shared. As such, stories connect the storyteller to the listener. They offer the listener the opportunity to re-imagine themselves, to foster their moral sensitivity, to empathize. As beautifully stated by Meininger [193]:

> In this connecting telling of stories, the strange is not denied or shoved aside but met in the conversation of people with themselves and with others. [...] no process of social integration is conceivable without having its starting point in a careful hermeneutics of the voice that is heard in the life story, the life world that is unlocked by the story, and the connections that the story implies or to which it invites the listener.

Similarly, Houben et al. [141] discuss the role and potential of collaborative and creative activities, like music-making, in enhancing social engagement and communication. The paper illustrates the importance of facilitating shared forms of expression and reinforcement of agency, recognizing the imbalance often present in different roles (such as caregiver and patient) and how technology can help it to be shifted towards equal partnerships.

2.9.2 Making as an Inclusive Practice

Building opportunities for socialization that enable people to become storytellers and listeners is thus a step towards realizing inclusion rights [1, 193]. Technology that is both accessible and inclusive can assist in empowering people to put on their storyteller hats. Digital storytelling has altered the way we communicate by serving as a mediator, increasing participation, and fostering identity formation [164, 225, 311]. Technology can help by providing different sensory stimuli, which improves engagement and learning [188] while also better adapting to each person's sensory needs [320] and allowing them to share a story "in the way [they] think and feel" [254]. Whether the social element is intentional or not, technology as a facilitator can promote fun socialization and communication [319]. The content of this sharing is typically related to the person's interests, which helps in "communicating the story of who an individual is" [319]. Interests can also be shared through interactive tangible devices designed to encourage creativity in telling one's own story [320].

Creating and creativity are best represented by makerspaces. Makerspaces are community spaces characterized by their sharing nature that fosters socialization: aside from sharing interests, there is a sharing of skills and expertise, as well as a pure sharing of the joy of *making* something [109, 289]. Opening access to makerspaces and maker culture is a concern addressable and addressed by technology [87, 109, 142, 289].

For instance, TIP-toy was created by Barbareschi et al. [28] to foster computational skills in children with mixed visual abilities. The main goal of the activity was to learn basic concepts like sequences, events, and loops, as well as basic processes like debugging, and the main outcome was music. Music can be easily applied to basic computation concepts, but it also involves creativity and sharing, so the side effect was the importance of collaboration and success celebration [28]. Buechley et al. [53] recorded similar reactions for LilyPad Arduino, which engaged children in sharing their wearable works of art. LilyPad Arduino is a microcontroller designed for inclusive computing experimentation, primarily with children [53] but also with the elderly [146] and people with intellectual disabilities [113]. LilyPad enables creators to improve fabric material and explore the world of wearables [53]. However, if the creator lacks dexterity, the sewing activity is difficult: imprecisions can result in a short circuit, assuming that the person knows how to sew, and the sewing machine is recommended [146], making it less accessible. Furthermore, managing the microcontroller and the components can be difficult: the fabric requires special care to avoid tearing, and small elements are difficult to manipulate [146]. The significance of dimensions in making components accessible was discovered by Hollinworth et al. [87], where their LittleBits were reported to be difficult to handle by people with intellectual disabilities, prompting them to "go LARGE" [138]. LittleBits are electronic kits that aim to raise technology awareness and computational skills, while also developing idea communication for creative purposes. They noted that when adapting a maker kit for inclusivity, affordances should be clear in terms of what the component does and how it should be connected to other pieces [137]. Ellis et al.'s [87] TapeBlocks address the challenges of dexterity by proposing one block with conductive tape per each component. To activate the component, the conductive tape of the block must come into contact with the conductive tape of a battery-powered block. Because of its simplicity, it allows for a low entry barrier without sacrificing the kit's tinkerability [87]. Another critical factor was maintaining engagement: the kit needed to give people the freedom to do something personally meaningful [87]. The making activity also promoted creativity and social connections, with participants helping each other out and sharing their creations during the workshop, according to Senaratne et al. [262]. TronicBoards, a toolkit of interchangeable boards, provided a similar experience in which participants collaborated to create artifacts that were personally meaningful to them, demonstrating their preferences and interests in the making process [262].

2.10 Artificial Intelligence

2.10.1 Technologies for Inclusion of People with Intellectual Disabilities

Societal norms frequently impose ways of communicating that don't align with how people with intellectual disabilities express themselves, leading to reduced social interactions [191] and less satisfying relationships [62] compared to those experienced by neurotypical individuals. In Australia, people with intellectual disabilities are among the most marginalized and disadvantaged groups [38]. Technology offers avenues for people with intellectual disabilities to engage in activities they might otherwise be unable to participate in due to physical or social constraints [232]. People with intellectual disabilities have displayed interest in adopting both novel and mainstream technologies [119] and their utilization of technology has seen growth in recent times [219].

Museums have begun incorporating technology to make their exhibits more engaging and inclusive. Augmented and Mixed reality has been used to immerse museum-goers in interactive storytelling experiences [124], and immersive technology in museums led to more people visiting [263]. Technology tools to assist visually impaired people to navigate and learn about art exhibits have improved their museum experience and encouraged them to visit museums more often [18]. Assistive robots have also been used to guide and describe exhibits to visually impaired museum visitors enabling them to safely and independently explore the museum at their own pace [156]. Museums should also cater to people with intellectual disabilities. Low sensory areas and providing items like noise-canceling headphones can help with issues with overstimulation [140]. Maps and wayfinding apps with different modalities for varied abilities can help people navigate the museum. Exhibits that have tactile interactions, including a touchscreen that provided immediate feedback, were liked by people with autism [140].

2.10.2 Artificial Intelligence and Accessibility

AI can support people with diverse abilities by providing different modalities for engaging with media. For example, automatic alt-text by Meta has helped people with visual disabilities engage with their social media platforms [327], AI-supported image recognition can compare uploaded images with related photos to provide automatically generated image descriptions [2] and AI-based voice recognition can create automatic captioning for videos on streaming platforms.

Furthermore, people with cognitive disabilities (an umbrella term that includes people with intellectual disabilities) can benefit from the functionality of platforms like ChatGPT to summarise text and replace difficult-to-read words with words that are easier to read [23]. ChatGPT is a large language model trained by OpenAI. Generative Pre-trained Transformer (GPT) models use natural language processing to read and create human-like text [23]. ChatGPT can also automate accessibility features like text-to-speech captioning [45].

Generative AI can help autistic people who struggle with making eye contact by modifying live video content so that it looks like the person in the video is making direct eye contact with the viewer [111]. However, public sentiment among neurotypical and autistic people towards this technology is split where some believe that it could help people to communicate more confidently but others voiced concern over normalizing the neurotypical norms for autistic people.

2.10.3 Augmenting Abilities with Artificial Intelligence

AI-generated art has been progressing as a type of modern media and digital artistic expression since the middle of the 2010s [250]. During the initial phases of AI art, a small group of artists employed data and machine learning (ML) as creative elements, in combination with enhancements in model design derived from research breakthroughs [250]. During the beginning of the 2020s, a series of breakthroughs in machine learning significantly transformed AI art, propelling it from a specialized artistic endeavor to a widespread cultural phenomenon. These accomplishments expanded the possibilities of text-to-image generators, making their exploration unrestricted and available to the general public [250].

Text-to-image generation platforms can be used as a form of self-expression and to visualize ideas that people have in their heads [250]. Generative AI platforms like Midjourney have been used to generate speculative designs and visually represent artifacts that have not been brought into existence yet [171]. This process can give rise to a fresh and realistic embodiment of concepts. Both the human and the computer are influenced by each other's inputs, leading to a shared creative responsibility for the final product [74]. This new approach involves a blending of computer and human initiative, and the partnership of human-computer co-creativity can be observed as flourishing along a spectrum spanning from human creativity to independent computational creativity [82].

However, there are some concerns when it comes to the use of AI. One of the main concerns with internet-based AI technology is the collection of user data, the issue of consent, and how this data is being used [2]. The collection of sensitive data can particularly lead to risks to the safety and privacy of individuals with a disability. Another concern is the algorithmic bias that is present. ChatGPT and similar language models have the potential to sustain or magnify pre-existing biases present within the training data they utilize [45] and even spread misinformation.

2.11 Conclusions

The literature review chapter comprehensively explored the intersection of individuals with intellectual disabilities, HCI, and accessibility. It outlined key theoretical frameworks and methodological approaches, highlighting the lack of literature specifically addressing the integration of individuals with intellectual disabilities within HCI and accessibility research [178]. The review underscored the importance of understanding intellectual disabilities, which vary in severity and impact cognitive, social, and practical domains, requiring tailored support and inclusion in digital and learning environments.

The chapter then discussed the role of technology and design in enhancing accessibility for individuals with intellectual disabilities. It examined the shift towards engaging individuals with disabilities as equal partners in the design process, emphasizing the need for accessible design and the inclusion of these individuals in early design stages to prevent high abandonment rates of assistive technologies. Furthermore, the literature review explored innovative strategies such as the use of "experts" in intellectual disabilities for co-designing workshops, leveraging scaffolding to support participation and the significance of multimodal communication in research involving individuals with intellectual disabilities.

The literature review highlights significant gaps in the direct involvement of people with intellectual disabilities in the design process, the assessment of technologies such as AR and social robots, and the inclusivity of cultural and learning environments such as museums. Despite advances in accessibility and assistive technologies, there remains a notable lack of research that actively integrates individuals with intellectual disabilities as co-researchers or main contributors, rather than merely subjects. Additionally, while several technologies have shown promise in enhancing learning and engagement, there is a shortage of comprehensive studies on their long-term effectiveness, usability, and acceptance among people with intellectual disabilities. There is also an urgent need to tailor these technologies to meet the diverse needs of individuals with intellectual disabilities effectively, to enhance their quality of life genuinely. Regarding cultural and learning environments, especially museums, more rigorous research is needed to make these spaces truly inclusive. Although some progress has been made for people with physical and sensory disabilities, those with intellectual disabilities have been largely overlooked. This gap extends to technology use in these environments, where integrating multisensory experiences and personalized learning approaches could significantly improve inclusivity for people with intellectual disabilities.

As we transitioned to Part I, Methodological Frameworks and Design, this groundwork informed the development of research methods that are sensitive to the needs of individuals with intellectual disabilities, ensuring their active involvement in the research process and the design of technologies that enhance their independence and integration into society.

Part I

Methodological Frameworks and Design

3

Methodology

The emerging trends presented in the previous chapter prioritize the active involvement of individuals with intellectual disabilities in the ideation and evaluation of digital and interactive prototypes. Their active involvement is rooted in the understanding of the unique needs, preferences, and abilities of people with intellectual disabilities, leveraging ICT to create accessible, engaging, and empowering experiences [39, 68, 87, 282].

Central to inclusive approaches is the adoption of a participatory philosophy, advocating for the active participation of individuals with intellectual disabilities in the design and development process of technological solutions [94, 113, 181]. The participatory methodology ensures that the resulting technologies are not only accessible but resonate deeply with the personal experiences and preferences of the users, fostering a sense of belonging and engagement. The methodology further relies on scaffolding strategies, offering temporary support adjusted according to the learner's progress, and improvisation, essential for accommodating the diverse needs of individuals with intellectual disabilities [105, 226, 324].

The literature highlights the importance of improvisation and co-design in developing solutions for various target groups, especially in critical situations. Improvisation [105], enhances learning, creativity, collaboration, and innovation in design, making it an essential skill for designers working in dynamic environments. Furthermore, the concept of Research through Design [334] promotes adaptability and responsiveness in co-design processes by reframing problems. Research through Design allows research to be more flexible and iterative, emphasizing continuous engagement with participants and the ability to refine and adjust based on their feedback and needs.

Communication plays a pivotal role in this design process. Effective communication with individuals with intellectual disabilities often requires extending beyond traditional verbal methods to embrace a variety of modalities, including sign languages, AAC devices, and other non-verbal forms [170, 179]. Recognizing and integrating these diverse modes of expression into the design process is crucial for accurately capturing the voices and perspectives of those with intellectual disabilities.

Caregivers are instrumental in supporting individuals with intellectual disabilities. Their deep understanding of the participant's needs and preferences is invaluable in the research and design processes. Still, it is vital to distinguish the caregivers' perspectives from those of the individuals themselves to ensure that the final designs authentically represent the users' desires and aspirations [132], shifting power dynamics [93]. Furthermore, adapting design and evaluation methods to meet the needs of individuals with intellectual disabilities is a critical consideration. Traditional HCI techniques, often based on verbal communication and abstract reasoning, may not be suitable for every participant [68, 132].

This chapter will outline the methodological frameworks guiding the research in subsequent chapters. Providing details about participants, research team, ethical considerations, data storage, and the research design overview, including studies on improvisation and scaffolding. These will base the discussion concerning the research questions. The findings and their implications will be further examined in Chapter 10.

This chapter also sets the stage for the exploration of a methodological research question, outlined as RQ 1: "How can we design technologies with and for people with intellectual disabilities?". This broad RQ is subdivided into three smaller ones:

- RQ 1.1: How can we involve people with intellectual disabilities in participatory design?
- RQ 1.2: How can we involve people with intellectual disabilities in the evaluation of digital and interactive prototypes for museum visits?
- RQ 1.3: How can we use technology to involve people with intellectual disabilities in creative and multisensory experiences?

3.1 Participants

The studies available in this doctoral dissertation involved thirty-two participants across three countries – Switzerland, Italy, and Australia – over eight research sessions. Each session could take one single day or a week and was designed to integrate individuals with intellectual disabilities into activities related to art and technology, reflecting their interests and preferences.

Swiss Study (Participants P1 to P5): The sessions conducted in Lugano engaged five participants affiliated with an association that supports individuals with intellectual disabilities. These participants, who typically engage in work and leisure activities organized by their association, participated in research sessions that were part of an "art and coffee" program. The Swiss association facilitated the recruitment process and ensured that the study received approval before starting. The studies conducted with Swiss participants are described in this chapter, on the improvisation methodology available in Section 3.7.

Italian Study (Participants P6 to P26): In Trieste, twenty-one participants were involved in sessions that complemented their routine of visiting museums and engaging in educational activities. Most of these participants are skilled in creating easy-to-read translations and worked alongside educators to adapt museum texts into accessible formats. The Italian sessions focused on using technology for engagement and informal learning, including studies with augmented reality, accessible applications, multisensory experiences, and electronic making and creative expression, detailed in Chapters 4, 5, 7, and 8.

Australian Study (Participants P27 to P32): Six participants in Brisbane attended workshops as part of "Museum outing" activities organized by their support centers and were invited to participate in our research. They can attend activities with their support center one or more days a week. The Australian sessions focused on cutting-edge technology to engage and enhance creativity as presented in Chapters 6 and 9.

Nonetheless, in all countries, participants could choose whether to be part of the study and be free to drop out at any point. The institutions we collaborated with in Switzerland and Italy provided their diagnosis while the research in Australia did not disclose specific information, aligning with the scope of the studies conducted there. Finally, table 3.1 denotes the participants of all studies.

3.2 Research Team

Throughout my doctoral dissertation, I had the privilege of working with an exceptionally diverse and talented research team. The team was comprised of two computer science professors, three Ph.D. students in computer science, one master's student, and three bachelor students also in computer science. Our technological perspective was strengthened by a psychologist, three psychology stu-

Table 3.1. Participants with intellectual disabilities presented in this doctoral dissertation.

PID	Gender	Age Range	Country	Attendance	Disabilities
P1	Woman	55-60	Switzerland	RV1 and RV2	Mild Intellectual Disabilities
P2	Man	30-35	Switzerland	RV1 and RV2	Mild Intellectual Disabilities
P3	Man	45-50	Switzerland	RV1 and RV2	Mild Intellectual Disabilities
P4	Man	25-30	Switzerland	RV1 and RV2	Mild Intellectual Disabilities
P5	Man	25-30	Switzerland	RV1 and RV2	Mild Intellectual Disabilities
P6	Woman	20-25	Italy	RV3 to RV5	Moderate Intellectual Disabilities
P7	Woman	40-45	Italy	RV3 to RV5	Moderate Intellectual Disabilities
P8	Man	30-35	Italy	RV3 to RV5	Moderate Intellectual Disabilities and Epilepsy
P9	Man	60-65	Italy	RV3	Mild Intellectual Disabilities and Tetraparesis
P10	Woman	30-35	Italy	RV3	Mild Intellectual Disabilities
P11	Woman	50-55	Italy	RV3 and RV5	Moderate Intellectual Disabilities and Spastic Paraparesis
P12	Woman	50-55	Italy	RV3	Moderate Intellectual Disabilities
P13	Woman	20-25	Italy	RV3 and RV4	Mild Intellectual Disabilities
P14	Woman	20-25	Italy	RV4 and RV5	Mild Intellectual Disabilities
P15	Woman	50-55	Italy	RV4 and RV5	Moderate Intellectual Disabilities
P16	Woman	60-65	Italy	RV3 to RV5	Mild Intellectual Disabilities and Down Syndrome
P17	Man	25-30	Italy	RV3 and RV4	Moderate Intellectual Disabilities and Non-verbal
P18	Woman	45-50	Italy	RV4 and RV5	Severe Intellectual Disabilities
P19	Man	50-55	Italy	RV4 and RV5	Mild Intellectual Disabilities
P20	Man	45-50	Italy	RV3 to RV5	Mild Intellectual Disabilities
P21	Man	55-60	Italy	RV4 and RV5	Moderate Intellectual Disabilities and Oligophrenia
P22	Woman	45-50	Italy	RV3	Moderate Intellectual Disabilities and Down Syndrome
P23	Man	20-25	Italy	RV4	Severe Intellectual Disabilities and Speech Disorders
P24	Woman	50-55	Italy	RV5	Moderate Intellectual Disabilities and Down Syndrome
P25	Woman	55-60	Italy	RV5	Moderate Intellectual Disabilities and Oligophrenia
P26	Woman	25-30	Italy	RV5	Moderate Intellectual Disabilities, Non-verbal and Down Syndrome
P27	Man	45-50	Australia	AW1 to AW3	Intellectual Disabilities
P28	Man	45-50	Australia	AW1 to AW3	Intellectual Disabilities
P29	Woman	35-40	Australia	AW1 to AW3	Intellectual Disabilities
P30	Man	20-25	Australia	AW1 to AW3	Intellectual Disabilities
P31	Man	20-25	Australia	AW3	Intellectual Disabilities
P32	Man	20-25	Australia	AW2	Intellectual Disabilities

dents, two special educators, several support workers, cultural mediators, and museum curators.

Each member brought their own set of skills and insights contributing to the dissertation in multiple ways. From conducting research sessions to recording valuable data, from developing specific parts of our projects to contributing to and reviewing research papers, their efforts were essential. As the first author of all the papers included in this dissertation, I had the opportunity to lead projects and directly observe the impact of our collaborative efforts. It was through this collective endeavor that the research presented in this dissertation was brought to fruition, it would be impossible to do all of these studies without their valuable contribution.

3.3 Ethical Considerations

In conducting the studies, ethical considerations and safe data storage were crucial to ensure participants' privacy, dignity, and autonomy. All the researchers handled data with the highest care, emphasizing the role of educators in maintaining the confidentiality and respect of sensitive data, including personal preferences and modes of communication. To secure data storage, electronic records were stored on local servers and only accessed for research purposes.

Informed consent was obtained from participants or their legal guardians. Researchers or the participant's association or support center took care of this process before each research session. We communicated the purpose and scope of our research, the data collection methods, and the intended use of information, reinforcing the voluntary nature of participation and the freedom to withdraw at any time without consequences. Open communication with educators and support workers was also prioritized to cater to any concerns or specific needs related to the participant's well-being.

The data collection involved audio and video recordings, with stringent measures to anonymize sensitive information before secure storage. Data analysis was conducted through debriefings, annotations, pictures, and video recordings, utilizing different tools (e.g. Miro board) for thematic mapping and clustering relevant information related to each session, ensuring thorough and respectful handling of participant data and contributions.

Finally, the studies were approved by the associations and support centers we collaborated with, and by the Swiss and Australian universities. USI under Decision CE-2023-11 and QUT under protocol number 2000000213.

3.4 Epistemological, Theoretical, and Methodological Positioning

This research adopts a **Constructivist Epistemological position**, reflecting a commitment to understanding the subjective experiences of individuals with intellectual disabilities as they interact with technology. This position is grounded in the belief that knowledge is a construct of human experience [36], influencing the methodology choice of this doctoral dissertation and the process of understanding the unique needs and preferences of the participants.

This research presupposes that the reality and meaning of technology used in museum and creative settings for people with intellectual disabilities are not pre-existing and waiting to be discovered [41]. Instead, these realities are constructed through the participants' experiences and interactions with the technologies. By involving participants in the design process, this doctoral dissertation acknowledges that their perspectives are crucial in shaping the technologies in a way that is meaningful and accessible to them.

In adopting a constructivist epistemology, this research rejects the generalization for all scientific questions [66]. It underscores the importance of enabling flexibility that is responsive to the participant's needs and the context of their interactions with technology.

Theoretical positioning of research comprises assumptions and principles to gain insight and provide explanations for observable events, occurrences, or situations known as phenomena [290]. This doctoral dissertation is grounded in the **Social Model of Disability**, which views disability as a result of societal barriers rather than individual impairments [264]. Chapter 2 emphasizes the societal construction of disability and this doctoral dissertation challenges the conventional perspectives that often limit the participation of individuals with intellectual disabilities in cultural and educational activities.

Employing the principles of **Critical Disability theory** [110], this doctoral dissertation critically examines the dual role of technology as both a facilitator and a barrier to access for people with intellectual disabilities, advocating for their empowerment by actively involving them in the design process of technology to challenge and redefine societal norms and structures that perpetuate the discrimination or social prejudice against people with disabilities [110], called ableism.

Methodological positioning reflects the underlying epistemological approach which guides the choice of techniques, methods, and strategies employed in gathering and analyzing research data [290]. This research employs a **Participatory Design approach** by involving participants with intellectual disabilities in all design steps, ensuring the technology meets their specific needs and preferences. Participatory Design promotes democratic values, collaborative efforts, active participation, investigative processes, and empowerment in the exploration of design research [46].

Also, following the **Affordance Theory** [302], the exploration of technologies like AR, MSD, EmpowerBox, and social robots to make content more understandable suggests an underlying consideration of the affordances these technologies provide users with intellectual disabilities, highlighting the relationship between the physical characteristics of technology and how they can be perceived and used by participants.

To further enhance the methodological framework, this research incorporates Scaffolding and Improvisation as strategies. **Scaffolding** is utilized to enhance participant engagement by adapting the co-design sessions to their needs. We provided tailored support through verbal, gestural, and physical prompts and the gradual reduction of assistance (fading) when needed. Scaffolding can facilitate meaningful participation and empower users by making the design process more accessible and inclusive [120].

Moreover, **Improvisation** allowed the project to adapt to diverse constraints creatively, finding alternative ways to involve participants and stakeholders despite the COVID-19 physical and social barriers [277]. This adaptive response ensured the continuation of participatory design activities, highlighting the importance of flexibility and resilience in the face of challenges to maintain the involvement of all participants in the design process.

The exploratory nature of the various studies focuses on understanding and meeting the diverse needs of individuals with intellectual disabilities. By integrating Scaffolding, the research showcases a dynamic methodological positioning that focuses on creating accessible technology and on the process of engagement, learning, and empowerment for individuals with intellectual disabilities. The strategies also highlight the importance of flexible and adaptive methods in research and design and recognize the critical role of technology's physical and interactive features in shaping user experiences.

3.5 Timeline and Research Design

In November 2019, I started my PhD journey, beginning with a review of the existing literature. In this initial phase, we reached out to Lugano Arte e Cultura (LAC), where my supervisor had a previous collaboration, to set up sessions aimed at engaging individuals with intellectual disabilities in art and culture. This initial phase involved meticulous planning and coordination, resulting in a project proposal that received the green light from the museum's leadership.

As the world faced the outbreak of the COVID-19 pandemic in 2020, the imposed restrictions significantly disrupted our plans for direct engagement with our participants. Adapting to these challenging circumstances and while unable to conduct co-design sessions, I shifted my focus towards enhancing an AR project to make it more inclusive. This involved integrating features such as labels and text-to-speech options, with design decisions influenced by relevant literature. The outcome was the **AIMuseum** application, standing for Accessible and Inclusive Museum (available in Chapter 4). The application was designed to make museum experiences more accessible and inclusive. This period also included a survey examining the state of accessibility education in Switzerland, revealing a concerning situation in the local context, matching international studies [267].

Despite these obstacles, we conducted our first Research Visit (**RV1**) in October 2020, adhering to strict safety protocols. A timeline with this RV and the following activities is available in Fig. 3.1. These RVs, encompassing workshops and research sessions, were crucial for gathering insights outside the conventional academic settings, given the constraints on participant involvement at the University. My growing Italian skills allowed me to follow most of the discussions during these visits. What might initially seem like a weakness – the struggle to master a brand new language – seemed to have a positive outcome with the participants fostering a deeper sense of connection and empathy. Assisted by my supervisor, we took notes from our **observations**, analyzing varying attitudes towards art among participants, and sparking reflections on how technology – specifically the AIMuseum application – could enhance their museum experience.

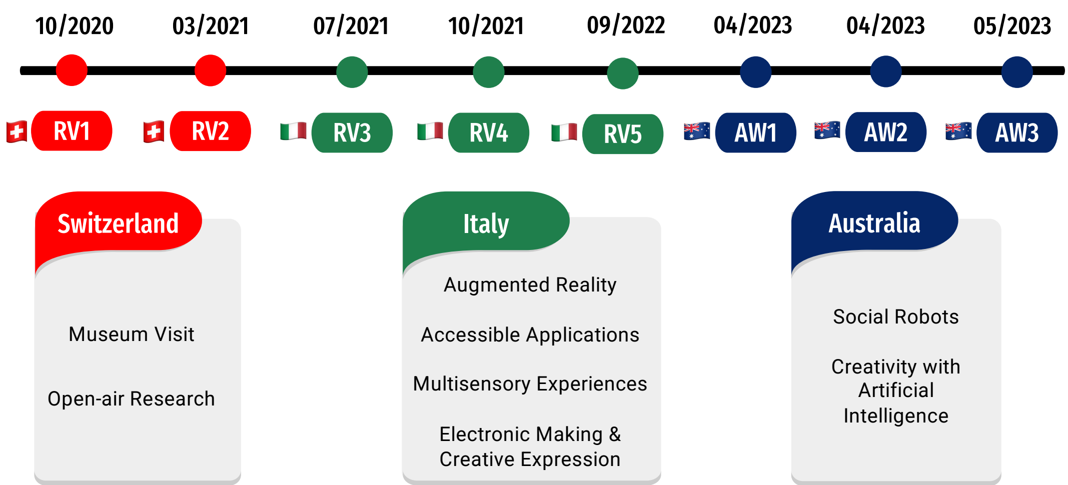


Figure 3.1. Research sessions timeline with the main studies/activities.

As an important side note, the design identity of many museums, characterized by minimalistic presentation and information on artworks, often fails to accommodate visitors with intellectual disabilities. This recognition prompted a broader consideration of accessibility, broadening its scope to include textual information comprehension and embracing the facilitation of **social interactions** and the employment of **alternative communication methods**. This expanded understanding acknowledges the challenge of directly eliciting feedback from participants about accessibility barriers, as their experiences are not readily compared with alternative options that might better meet their needs.

Addressing this issue necessitates a multifaceted research methodology, as relying solely on interviews is insufficient to gain comprehensive insights. The iterative process of engaging with our target group faced further obstacles due to evolving pandemic restrictions, necessitating constant **adaptation** of our research methodology. This phase involved exploring readily available resources like museum websites, virtual tour navigation, and leaflets as potential content for future testing.

Moving on, a breakthrough came in March 2021, when we finally reconnected with our participant group outdoors taking all necessary precautions to run the **RV2**. The insights from this session, which are detailed in Section 3.7, include conducting **interviews** and **demonstration of available tools**, underscore the importance of our **improvisation** and adaptation [277] as methods to deal with the unexpected. In the following research sessions, we used improvisation and conducted **research through design** [334] by emphasizing the importance of adaptability and responsiveness to the diverse needs and feedback of participants. Our research activities become more flexible and open-ended, allowing for continuous refinement and adjustment based on ongoing engagement with participants.

To navigate challenges related to access to participants with intellectual disabilities, we established a partnership with an institution in Trieste, Italy, which proved to be a pivotal decision. Participants attend the association daily, engaging in various activities designed to enhance their learning and comprehension skills, including the simplification of content into easy-to-read language. This setup in Trieste allowed for a more seamless research process. The institution is equipped with the expertise of special educators and psychologists specializing in intellectual disabilities, creating an ideal setting for both theoretical and practical exploration. Our engagement virtually and the research visits extending during a week, facilitated in-depth interaction with participants, allowing a richer data collection.

Transitioning the focus to museum engagement, we observed significant differences in participant engagement between modern art and natural science museums. In Switzerland, participants with intellectual disabilities visiting LAC focused primarily on abstract art interpretation, often relying on cultural mediators to simplify complex concepts. This contrasted with our observations in Italy, where the focus shifted towards understanding tangible subjects, like animals, in the Natural Science Museum.

Amid the COVID-19 pandemic, in July 2021, we successfully conducted a visit to Trieste. RV3 explored AR and accessible applications. Our methodology incorporated **co-design sessions** with **focus groups**, **usability testing**, and a **task-based activities**, aimed at understanding how participants interact with digital devices and content. This approach provided insights into the accessibility of technology for individuals with intellectual disabilities, highlighting the importance of intuitive design and the potential barriers posed by standard devices.

The evaluation session consisted of analyzing an existing museum website and a museum application. Our focus was on understanding the usage patterns of these tools by our co-designers. Due to the need to learn content in an accessible way, **ACCESS+** was born. The ACCESS+ application (Chapter 5) is dedicated to elevating accessibility to museum content, crafted with the specific needs of individuals with intellectual disabilities at its core.

Three months following our initial visit, we had our fourth research visit (**RV4**) back to Trieste, to better understand the functionality and reception of the AIMuseum and ACCESS+ applications. These sessions started by leveraging focus groups and evaluating prior knowledge to gauge participants' understanding of museum-related texts and contents, setting the stage for their museum experience. Our approach evolved to incorporate a task-based approach to the accessible features we designed, adopting an **iterative process** to refine the app according to participant feedback. This involved testing various accessible features, including text-to-speech, AAC pictograms, and adjustments in font and icon sizes. Through task-based activities and strategic **scaffolding** (available further in Section 3.8) – providing verbal, gestural, and physical prompts – we identified crucial UI design improvements, such as the need to inform the participants when they unintentionally blocked the camera with their fingers.

These sessions confirmed participants' interest in creative expression and social interaction. We started the design of a multisensory experience diorama (**MSD**) to enhance their museum experience (Chapter 7) and the **EmpowerBox** project, a multisensory self-representation box aimed at fostering self-expression and creativity among individuals with intellectual disabilities (Chapter 8). By research visit 5 (**RV5**) in September 2022, we had time to iterate our existing projects based on our previous co-design session findings and design the new projects, EmpowerBox and MSD. This phase introduced a novel approach, requiring accessible materials and **tailored assistance** for participants to construct their EmpowerBoxes. We gathered AAC pictograms from participants to personalize the materials, fostering a deeper understanding of our participants' preferences. The workshop demanded flexibility and adaptation to meet the diverse needs of verbal, minimally verbal, and nonverbal participants, with continuous scaffolding support throughout.

In 2023, I had a six-month doctoral mobility in Australia that offered a unique experience. My initial two months involved museum visits with participants from local support centers, observing how they interact with art and the role of their support workers in these contexts. Unlike our prior settings, these participants engaged with museums primarily for exploration and socialization, not for content comprehension. This observation highlighted the potential of utilizing cutting-edge technologies to enhance engagement, leveraging the resources available at the Australian university.

The three-week workshop series, comprising Australian Workshop 1, 2, and 3 (**AW1, AW2, and AW3**) introduced **social robots** as a museum co-facilitator (Chapter 6) and **artificial intelligence** inspiring creative expression (Chapter 9). The workshops were supported by the ACCESS+ application adapted to the Australian content. Through observations, **debriefings**, **participant drawings**, and focus groups, we gathered rich data on the effectiveness of these technologies in enhancing museum experiences for individuals with intellectual disabilities. These experiences and data collection phases informed the final stages of my doctoral journey. I dedicated the last months to writing academic papers and completing this doctoral dissertation. This comprehensive exploration advances our understanding of accessible museum experiences for individuals with intellectual disabilities and highlights the iterative, participant-centered approach crucial for developing meaningful technological interventions and creative collaboration.

3.6 Co-Design

Co-design developed from the long tradition of Participatory Design (PD), and it incorporates a variety of methods and techniques aimed at giving participants power over the design process. The primary distinction between Co-Design and PD is the lack of emphasis on ideology, which should be reclaimed [194]. Co-Design is then defined as "collective creativity as it is applied across the entire span of a design process" [253], emphasizing involvement in creative participation techniques.

Because of the focus on user engagement, different approaches target different user groups, including people with disabilities [237]. Co-design and user-centered approaches frequently rely on a standardized set of participant skills that may not accurately reflect the ones used by the participants to express themselves or conceptualize their experiences, or for which participation may be adapted as needed [132]. Additionally, researchers may not feel confident enough to involve persons with intellectual disabilities in the co-design process without instructions and assurance from the community [271], this may also be due to their inability to relate to the participants' experiences [132].

By reviewing prior literature and participating in expert-led workshops, Hendriks et al. [132] investigated the potential development of methods and strategies specifically intended to increase the engagement of people with intellectual disabilities in co-design. However, they realized that a single strategy did not adequately account for the variety of life experiences that people with intellectual disabilities have, leading to advocacy for more individualized and adaptive design techniques [132], emphasizing the need to disseminate the lessons learned and adjustments needed while developing research methods to create a body of research that may enhance the future of accessibility.

When involving individuals with intellectual disabilities, it is crucial to have multiple means of eliciting needs while also keeping attention and engagement [108]. As an example, Co-Design Beyond Words (CDBW) aims to facilitate various forms of expression that do not depend on verbal communication, which amounts to a reflection-in-action process [318]. To enhance user engagement and bridge the knowledge gap between researchers and participants, one approach is to involve users with concrete objects [108] [318] or prototypes that can aid in increasing their involvement [39] [282] [325] [121].

Also in response to these challenges, innovative solutions have been proposed, such as engaging "experts" in intellectual disabilities to design workshops that are more accessible and engaging [108]. Such strategies, alongside the broader shift towards co-design [33, 39], indicates a transformative change in the role of individuals within research. People are no longer viewed merely as participants or bystanders; instead, they are stepping into influential positions where they lead activities and make critical decisions. The shift is a huge step forward in the direction of more inclusive, participative, and user-centered design processes, ensuring that the co-designed products, services, and systems are truly reflective of the diverse society we live in.

3.7 Improvisation to Support Sessions

When designing with and for people with intellectual disabilities, meeting and planning sessions with participants are very important to understand their needs and foster inclusion, creativity, and usability. During the last few years, the COVID-19 pandemic brought new challenges and added an extra layer of complexity to the organization of sessions for understanding the participants, developing solutions, and testing them. We all had to adapt to masks, hand sanitizers, open-air meetings, excitement, frustration, and online video calls. In our project involving people with intellectual disabilities in the museum context, we also had to deal with museums being closed, physical exhibitions being canceled, and at times, exhibitions being offered in an alternative online version. All of these challenges have an impact on the way we engage and conduct research with people with intellectual disabilities.

Our participants are often part of associations and special schools, having family members, caregivers, or guardians responsible for their safety and well-being. As they can belong to high-risk groups, having direct access to them proves almost impossible, depending on the local level of alert and the corresponding measures taken by their guardians, who were really afraid of the possibility of our participants getting sick and took a very defensive close stand. To deal with the ever-changing situation, we propose to resort to improvisation. Here, for improvisation, we intend "...a creative act composed without prior thought" [105], and we refer to the work by Lee et al. [167] as an example of improvisation to deal with unexpected circumstances during collaborative design. This study will share our experience during the first research sessions (RV1 and RV2) and what we learned from coping with such a demanding situation by using improvisation.

3.7.1 Research design: Dealing with challenges and improvisation

In order to discover how to use technology to make visiting a museum a more accessible, rewarding, and memorable experience, we planned several co-design sessions that unfortunately could not take place due to the COVID-19 second-wave restrictions. From previous observations, we noticed that visitors' level of involvement was higher when exposed beforehand to material describing the artworks on display, but that was a demanding process for visitors and their educators. Therefore, we wanted to study how technology could help involve them in the visit. At the same time, we aimed to observe their reaction to the narrative provided by the cultural mediator. A comparison between our initial plans [274] and our results using improvisation can be seen in Table 3.2 and they will be discussed in this section.

Different from what we planned, we had only two sessions with our participants. The expectation was to have eight participants, but we had five who, luckily, were available in both sessions. They are all adults, three women and two men, with intellectual disabilities and ages varying from 30 to 61 years old. They all communicate in Italian, live in Lugano - Switzerland, and volunteer to participate in this research. One of the researchers had been working with this

Table 3.2. Comparison between our plans and final execution of the two Sessions. Main changes appear in italics.

Topic	What we planned	What we had
People	Cultural mediator, researchers, *experts*, and *eight* participants	Cultural mediator, researchers, and *five* participants
Time	Meeting *one week* after the first meeting	Meeting *five months* after the first meeting
Place	Museum and *lab*	Museum and *open-air*
Accessibility	Online and physically accessible exhibitions	*Restrictions to physical exhibitions*
Restrictions	Freedom to meet in closed spaces	COVID-19 restrictions: private *gatherings of five people* from two households
Activities	*Contextual inquiry* (Field observations and Interviews), *Co-design hands-on activities, Individual use of technology*	Field observations, Interviews, *Researcher demonstrating the available tools*
Ratio	*Five to eight* participants	*Three to five* participants

group before and established a more open link in terms of communication.

We had access to the participants through an association taking care of people with disabilities and offering them extra activities for their free time, such as "art, chat and coffee" sessions from their culture and education training program. They are keen visitors to art exhibitions and museums in the last few years. Besides, we had also planned to involve a few experts in intellectual disabilities but given restrictions on the maximum number of participants they could not join us, and so, we missed their valuable insights as well as their help as entertainers during the study.

3.7.2 RV1: Observing the participants in the museum

The first session (Fig. 3.2a) happened, after some attempts, in October 2020 at a local museum called LAC. The whole session took around 2 hours and aimed to understand the user's needs in the museum context. The participants visited a temporary exhibition in a guided tour composed by the participants, cultural mediator, association director, and the authors of this study. To start, we chose a meeting point in front of the museum. After the five participants arrived, we entered the museum using masks and hand sanitizer. While wearing a mask can be part of the life of some people with disabilities, this is a situation our participants never had to face before, and they had to adapt. The cultural mediator[1] helped visitors to familiarise themselves with the building and with us. She also described what would be their role in the project and the details of their collaboration in the study. She collected their consent as required by our ethics process [204] together with that of their guardians obtained in advance. Once visitors had agreed and were happy to collaborate with us, the cultural mediator guided them to store their belongings in the lockers, and finally, to visit the displayed artworks.

(a) RV1 (b) RV2 - Part I [2]

Figure 3.2. Pictures from the different Sessions that happened during COVID-19 pandemic.

The guided tour took around 40 minutes. We made an ethnography study and collected data by observing the participants' behavior during their visit, recording audio, and taking notes without interfering in their interactions with the cultural mediator and artwork. We tried to be the most discreet we could to make them feel comfortable with their visit.

The cultural mediator engaged in dialogue with the visitors by asking several questions related to the artworks, their personal experiences (a strategy to recall memory and avoid abstraction), and the context where the artworks were inserted. The participants were very different between them and had different reactions and personalities, such as:

- Participation: one participant was extremely positive and participative.

[1]The cultural mediator is part of our research team
[2]Picture by Elia Bianchi

She answered almost all questions or repeated other participants' answers;

- Laughing: one participant was constantly smiling, laughing, and showing his contentment to be part of the visit;
- Brief answers or no participation: one participant was very quiet, with no answers or extremely brief ones;
- Getting comfortable: a participant was quiet during the first half but, after getting comfortable, answered the questions.
- Concentration: One participant was constantly asking for silence verbally or with the "shhh" sound.

Finally, after the meeting, we also had a coffee, a snack, and a chat together. Therefore, we planned to meet one week later as part of our contextual inquiry to discuss how the visit went. Unfortunately, we could not proceed because the cultural mediator was sick. We postponed to the following week, but then we faced the COVID-19 second wave restrictions: avoid closed places and gatherings of more than five people. The safety measures had a massive impact on our plans. Alternative solutions, such as synchronous online meetings, were not possible because of the lack of access to computers and available guidance on how to attend online meetings. After months of unsuccessful attempts, the cultural mediator kindly volunteered to meet the users one at a time, in person and open air, to help them get connected and proceed with the following research steps. In the week we were going ahead with this solution, Switzerland announced to relax the safety measures and soon it would be possible to meet open-air in a group of up to 10 people, so we proceeded with the in-person plan.

3.7.3 RV2 - Part I: Remembering the visit collectively in open-air

After a few cancellations due to participants being unwell, we finally managed to meet our co-designers with the relaxation of restrictive measures in place locally in March 2021. As required, we met them in a park, wearing masks, with plenty of quiet corners to sit and chat. We scheduled the meeting on a Saturday to allow our co-designers not to miss a working day as they work during the week and attend these activities in their free time. The cultural mediator joined us too. We had asked permission to record our conversations and divided the meeting into two parts. In the first part, a collective one, as in Fig. 3.2b, we encouraged our participants to recall what they had seen in the museum on their previous visit. To help them remember, given that a few months had passed since then, we showed them the exhibition through an iPad. We presented the museum's official virtual tour (3D navigation) and redid the path they visited in RV1. The works were described by the same cultural mediator, with highlights to the most memorable ones. Everybody liked to visit the virtual exhibition and to choose where to navigate and what to see. This first activity was intended to get us back into the mood to discuss how to make the experience of visiting a museum more rewarding and engaging.

3.7.4 RV2 - Part II: Individual interactions

After a break for a snack and a chat, we moved on to the second part of the meeting. We approached each of our co-designers individually, keeping the required distance and using hand sanitizer and masks. We asked a few questions about their attitude, preferences, likes, and dislikes when visiting museum exhibitions. Each session took about 10 minutes. We started by showing the static website of the exhibition, with pictures of the artworks. We followed literature and advice from experts to make sure to ask questions in a way that was conducive to further elaboration and not just a yes or no answer. Then, we asked if they preferred the static website or the 3D navigation and if they would like to read on the iPad or paper. We also asked how they usually access information and if they use mobile phones. Next, we showed a prototype, called AIMuseum [122], an accessible augmented reality app to interact with virtual artworks via Quick Response (QR) code, with text-to-speech information. The content was related to the visited exhibition. Even accounting for the novelty effect, we were delighted with their unanimous, spontaneous, and positive reaction and the expectation it created in our participants. Lastly, we showed a multimedia app with text-to-speech content about museums and asked them if they preferred read-aloud techniques or to read alone. We used improvisation to keep participants engaged and avoid distraction by choosing when and how to run individual and group activities. Still, because of the restrictions, we could not run the originally planned co-design session. Nonetheless, we achieved a good understanding of our users and are ready for the next ideation stage.

3.7.5 Conclusion and Future Works

By engaging our participants in a series of activities, some carefully planned, and some more improvised, we managed to understand their needs better. As future online meetings have been discarded, we need improvisation and flexibility to take advantage of the rare occasions when it is possible to meet in person, bringing at times more successful results than trying to achieve consistency and accuracy at all costs. A possible solution would be to involve other stakeholders and apply multimodal qualitative research, where researchers collect data using more than one method, prompting participants in different ways and then generating multiple forms of the same data. We should be ready to quickly adapt our research plans, including finding the right time and space to share content with the participants, keeping them engaged and avoiding distractions, and changing the order of individual and group activities.

3.8 Applying Scaffolding to Co-Design

In the paper resulting from this study, we used the W3C COGA definition of cognitive disabilities [261], which includes, but is not limited to: cognitive disabilities, learning disabilities, intellectual disabilities, and specific learning disabilities. For this reason, while the paper uses the umbrella term "cognitive and learning disabilities", I will keep the name intellectual disabilities that are used throughout this doctoral dissertation.

When running technological projects aimed at people with intellectual disabilities, supporting procedures should be used to enable participants to solve a task, express their ideas and desires, or both [59]. Based on the homonymous metaphor [324], Scaffolding, an evidence-based educational practice (EBE), has a long history of application and success in facilitating the learning of people with learning disabilities. Typically it involves a structured interaction between a knowledgeable other (e.g., educator, researcher, caregiver, support worker) and a learning protagonist (child or adult), intending to help the latter to achieve a specific goal by providing tailored assistance [61]. This study involves technology and tools as a way to assist people with intellectual disabilities (Figure 3.3). The concept of scaffolding is conceived around introducing temporary support to help achieve an objective that would otherwise prove out of reach. The supportive elements are subsequently removed when they are no longer needed. Scaffolding enables transferring these symbolic elements into different contexts, such as the well-known learning one and the specific acquisition of technological skills.

Scaffolding procedures seem particularly promising in supporting co-design activities in the various phases of ideation, prototyping, and evaluation as well as earlier on during user data collection leading to the extraction of user require-

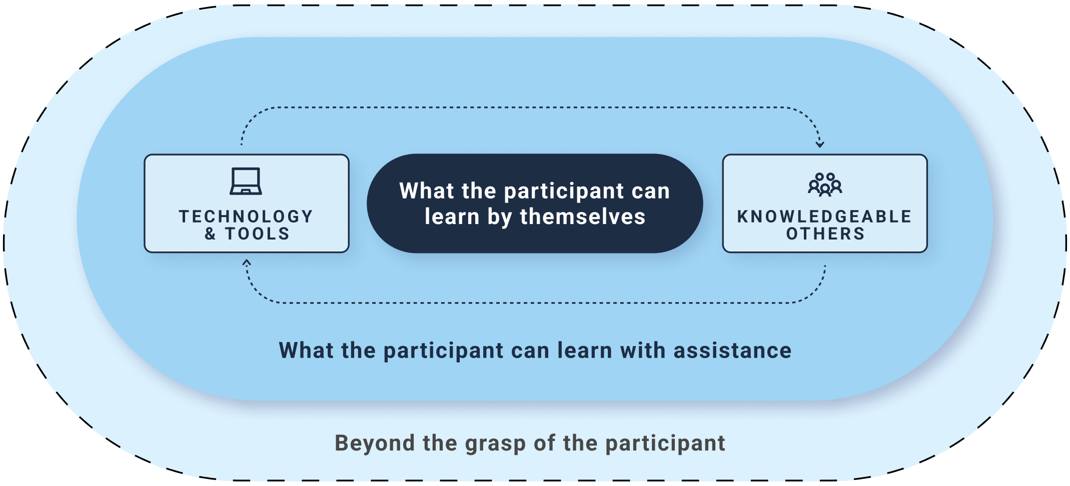


Figure 3.3. Participants' knowledge and assistance with scaffolding, based on [303].

ments. However, we could not find any study introducing guidelines to date. This study strives to comprehensively respond to the research question, "How can scaffolding effectively assist and empower individuals with intellectual disabilities to participate in the co-design of innovative technologies?"

We will focus on how scaffolding can help engage and empower participants involved in co-design activities, taking care of all the different design steps. Starting from making sure the focus of the design is clearly and effectively communicated, supporting the roles participants can play, and facilitating any proposed activity while collecting and assessing new ideas as triggered by having task-oriented interaction with existing tools. All of this is accomplished by using as many communication channels as appropriate, checking the need for further explanations, and providing those when needed. In doing this we also acknowledge the different forms of prompts to be accessible to our co-designers. In this study, we make three overall contributions to the HCI community:

1. We adapt and expand the concept of scaffolding first introduced by Wood et al. [324] as a metaphor to support learning, to be used in the collaborative design of technology with people with intellectual disabilities;

2. Describe case studies to empirically expose how scaffolding support can empower people with intellectual disabilities during co-design sessions;

3. Propose scaffolding steps as guidelines toward inclusive co-design.

While scaffolding has become common in co-design, there is no set of rules that standardize the approach for co-design tasks with people with intellectual disabilities. As a result, our primary focus is on using scaffolding to encourage their active participation in co-design. We intend to formulate guidelines for scaffolding to aid designers in carrying out such studies effectively.

3.8.1 Methodology

This segment presents a comprehensive overview of our data collection and analysis method, along with the ethical considerations we adhered to during the research process. It also provides detailed insights into the participants involved in our two case studies. These studies are practical applications of the scaffolding method in real-world co-design activities. Through them, we aim to deepen our understanding of scaffolding's role in enhancing collaborative design, thereby solidifying the foundations of our research findings.

Participants

Our research sessions included eight participants in total. In Case Study I, we had four participants (P6, P7, P8, and P9) attending in person and one participant (P10) attending virtually as she usually does. In Case Study II, we had seven participants (P6, P7, P8, P9, P11, P12, and P17). They are part of an association that supports people with intellectual disabilities and actively involves them in studying several topics on display at the museum. The association recruited participants who were asked to interact with the application as part of their daily study routine. Nonetheless, participants could choose whether to be part of the study and be free to drop out at any point. Table 3.1 denotes the participants' demographics.

Research Team and Collaboration

We worked with a multidisciplinary team during both case studies, including one educator and one assistant, a psychologist, and three computer science researchers. We collaborated with participants and professionals from the ANFFAS support center and with the Trieste Natural History Museum, which also provided access to their content and physical space.

Data Collection and Analysis

We recorded audio and video in a local cloud service for future data analysis, and access was strictly limited to the researchers conducting the research. All procedures were conducted by the authors.

Each participant session included an Educator as participant assistant, providing support when needed; the collaborating psychologist took notes, while a researcher conducted the sessions. All potentially identifying information was redacted in the transcription process.

Qualitative analysis was conducted, and we coded the data to extract categories, highlights, and trends. We adapted Gibbs' Reflective Cycle [5] as a framework based on thematic analysis [4]. This reflective model, consisting of six stages – Description, Feelings, Evaluation, Analysis, Conclusion, and Action Plan – allowed us to deeply examine our interactions, identify points of success, and continuously improve our research approach. We gathered notes, photos, and videos collected from the aforementioned studies, and we identified common threads and patterns of experience, extracting insights useful for developing guidelines.

Ethical Considerations

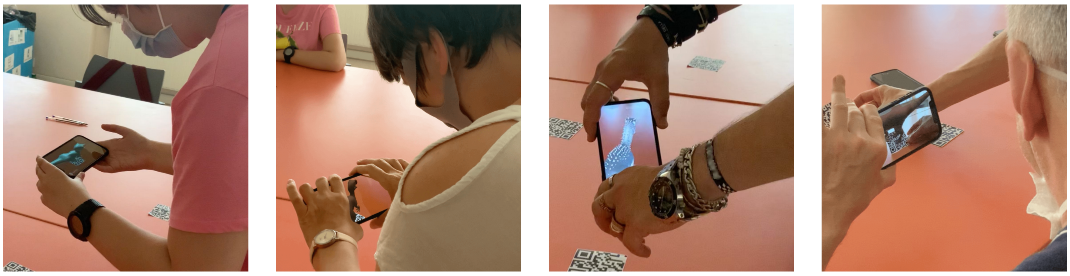
We applied strict security protocols in handling participant data from our Case Studies. The partner association handled communicating consent, ensuring each participant and their legal guardians were aware of the study and informed them of the possibility of discontinuing participation at any time. Additionally, the research was reviewed and approved by the Ethics Committees of the institutions involved (USI – Decision CE-2023-11 – and ANFFAS).

3.8.2 Case Studies

The following case studies helped shape a co-design structure that focuses on increasing, and interpreting the participation of people with intellectual disabilities. Each case study has its own goal, participant pool, assessment criteria, and findings. The technologies supporting these case studies will be explored further in Chapters 4 and 5.

3.8.3 Case Study I: AR interaction

This Case Study revolves around scaffolding when designing an Augmented Reality (AR) application called AIMusem [122] and assessing the interaction and perception of AR by people with intellectual disabilities before, during, or after a museum visit [119]. We designed and developed an application to test how AR can provide support and is perceived in this context. The project's primary objective was to create an inclusive AR experience that would assist participants in engaging with museum content. In this Case Study, we are focusing on the 3D dinosaur exhibits. Participants were instructed to complete three tasks using a smartphone camera (1) target the Quick Response (QR) codes of a brown dinosaur, (2) target the QR code of a white dinosaur, and (3) read the textual description or use a text-to-speech (TTS) feature to hear the text read aloud. Fig. 3.4 illustrates participants engaging with the application.



(a) Participant P6 (b) Participant P7 (c) Participant P8 (d) Participant P9

Figure 3.4. Participants interacting with dinosaur content using an AR application.

Findings:

The analysis revealed the following themes:

Using scaffolding to assess understanding: During the session, we encouraged participants to interact with AR. We realized that instructions like "*Please, approach the object*" were ambiguous to P6, P7, and P8 since it was unclear whether the object referred to was the device or the QR code. They interpreted it to mean bringing the device closer to their face rather than bringing it closer to the QR code– the intended action. To address this, we employed a well-established method of providing instructions with a **time delay**. Initially, we assisted in guiding the motion using a **physical prompt**. Then we used fading to reduce the physical prompt and replace it with **verbal cues** after the autonomous use of the smartphone was successfully learned. We also provided **gestural prompts** to guide the interaction, pointing to where they should move the device. When participants were presented with the words "*enlarge*" or "*reduce*," the same misunderstanding arose, as the object of the action was unclear.

Prompting or explaining: P7 unintentionally covered the smartphone's camera with her fingers and questioned whether the power had run out. Once we informed her that her fingers were causing the obstruction, she modified her grip and repositioned the device to uncover the camera. Our **verbal prompt** prevented her from becoming frustrated and enabled her to complete the task successfully.

Assisting a participant: P9 has a motor disability. The participant easily accomplished all of the tasks and only needed assistance holding the smartphone and focusing on the QR code. The **physical scaffolding** he required was related to his motor ability: knowledgeable others assisted him in achieving the proposed goal by helping him hold the device.

Providing peer feedback: Participant P10 needed a few minutes to understand how AR functioned and behaved as she interacted with it through her computer screen. Initially, she thought it was a video, and we demonstrated how both work (the camera and the QR code) so she could associate that the camera was pointing at the QR code and generating the image on the screen. We used text-to-speech to describe the 3D object, a dinosaur, with the following sentence: "Hi, I am a dinosaur". After carefully looking and listening, P10 was ready to express a critical perspective, she said: "*We have never met a dinosaur because it no longer exists, but it seems like a nice way of seeing it*". She added: "*It is a good idea for someone who can't read [to hear the dinosaur introducing itself]. You could provide generic audio like "Hi, I'm a dinosaur, I was alive, and I am not living anymore. I was herbivorous*". Scaffolding lowered obstacles to engaging with AR technology while creating an environment in which mistakes are the fault of the design, not of the user. Thanks to the feedback mechanism that it promoted, scaffolding framed the object of investigation as *in fieri*, encouraging a mindset of improvement and eventually making the participant act as an **expert**, a knowledgeable other (Fig. 3.3), providing concrete assistance for simplifying the content for her peers.

3.8.4 Case Study II: Accessible Application

This Case Study highlights scaffolding when co-designing a museum application called ACCESS+ [275][246]. We evaluated the usability of the museum website and a previous museum tablet application to gather feedback and requirements from participants and then we moved to iterate the design of the ACCESS+ app. To iterate and make ACCESS+ more accessible, the co-design process involved three research visits with stakeholders (museum professionals, educators, psychologists, and technology experts) and individuals with intellectual disabilities to understand their needs and collect requirements. In this study, we are providing examples and highlighting how we scaffolded the first research visit, composed of several days and research sessions.

Findings:

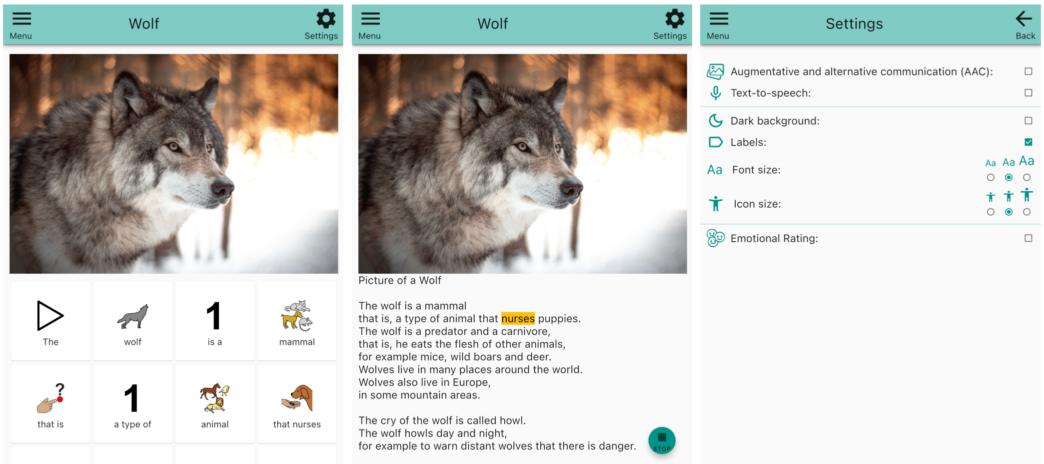
The following research disclosed several significant themes.

Eliciting previous knowledge to solve a task: In our first session, participants were asked to inform us about specific information provided by the website. For this task, participants were asked to identify when the museum was open. After carefully reading the page, participant P12 said, "*I don't recall by heart, but I went there in the morning last time; they presumably still open in the morning.*" Initially, the participant used her previous knowledge to answer the question, rather than information seeking the content of the website. We then specifically asked her to consider and focus on the content of the website and refer to the times listed there, helping her to get a better understanding of the task by also giving a hint on how to achieve it. After scaffolding, she provided specific times listed in the website's information, and she was able to derive the correct answer. In this example, the researchers provided a scaffold to support the participant's thinking process using **verbal prompts** and further scaffolding to help her retrieve the necessary information.

Expressing and acknowledging self-efficacy: We provided participants with **verbal and gestural scaffolding** as we tasked them with searching for the museum address and admission fee. We aimed to evaluate how comprehensible street names, numbers, references, and ticket prices were for them. Although all participants were able to complete the task, P6 stood out by completing it quickly and displaying a high level of self-efficacy: "*I told you I knew how to use the tablet*". Acknowledging and celebrating users' accomplishments can foster a positive and encouraging environment, which is crucial for their engagement in research tasks.

Scaffolding aiding navigation: In the first session using the ACCESS+ app, the first objective involved finding a particular animal within the menu. Upon reaching the correct page, a picture and the initial portion of content were presented (Fig 3.5b). To access more information, participants had to scroll down. While the majority of participants managed to scroll autonomously, a few required **verbal or gestural** prompts as a scaffolded approach. Notably, during this task, P9 encountered distractions and moments of frustration, necessitating a supportive atmosphere to facilitate full participation.

Scaffolding to understand audio and visual contents: We conducted tests



(a) AAC text (b) E2R text with TTS (c) Settings

Figure 3.5. ACCESS+ app with different features.

involving easy-to-read text paired with text-to-speech and word highlighting (refer to Fig. 3.5b). During these tests, P7 effectively utilized the TTS feature following **verbal** instructions. However, P12 encountered challenges in adjusting the voice speed to their preference. While some participants found the TTS feature to be beneficial, others required additional clarification or experienced difficulties in concentrating when simultaneously reading and listening to the text. Notably, P17, a non-verbal participant who relies on Augmentative and Alternative Communication (AAC) for communication, played a crucial role in the testing process. P17 communicated using their AAC notebook and **gestures**, offering valuable insights as a daily AAC user. Their input proved invaluable in identifying complex pictograms (see Fig. 3.5a). P17 expressed satisfaction with the ability to interact with the interface, listening to individual pictograms with the assistance of TTS. In P6's feedback, they described the experience as "*Very easy! I pressed an image, and the iPad spoke*."

3.8.5 A Framework for Scaffolding

When co-designing with people with intellectual disabilities, it is well understood that research sessions must be properly planned (e.g., [68][318][237]). Once researchers have completed their planning for the research visit and associated activities, they can employ scaffolding during the session.

This strategy is designed to assist and actively involve participants throughout the co-design session. Therefore, researchers can opt for an adaptable approach, recognizing that each participant may possess unique needs and capabilities. This customization may entail utilizing various communication methods, adjusting the session's pace, or modifying the content to cater to the specific requirements of each participant.

1. **Subdivide the test.** Initiate by subdividing the elements of your test (encompassing various activities and tasks) into small chunks. Introducing each concept at a time will help your participants to process and execute the tasks more easily.

2. **Initiating with a Task.** Following the subdivision of the test elements, introduce a task [147] while giving instructions on how to perform it. It is crucial at this stage to allocate sufficient time for participants to absorb and comprehend this information while considering the variability in individual processing capabilities.

3. **Assessing understanding.** Recognizing that participants, especially those with intellectual disabilities, may not always express their understanding verbally, alternative methods of assessment are crucial. Instead of always relying on verbal articulation, you can also encourage participants to demonstrate their comprehension through actions or any other form of expression (e.g. pointing to pictograms). For instance, rather than asking, "*What do you think this means?*", prompt them with action-oriented queries like, "*Can you show me how you would do that?*" or "*What would you do next?*" These practical demonstrations offer insights into their grasp of the concept. While assessing understanding in this manner, you may discover areas where the concept was not fully comprehended. By creatively encouraging participants to **show** rather than **tell**, their ability to execute a task can effectively reveal their level of understanding. This step can be executed more than once if needed. You can also use different strategies – such as allowing a bigger time delay for any prompt – as a way to accommodate the participants' needs. Additionally, when suitable, facilitating peer interactions can further enhance the assessment and learning process.

4. **Support understanding through prompting.** In contrast to conventional methods, where researchers typically avoid providing prompts or explanations to minimize bias, our approach involves the strategic use of prompts to aid participants in understanding and interacting with the tasks. Prompting can take various forms, such as verbal cues, gestures, physical aids, or a combination thereof. These prompts are designed to offer additional

contextual information, making it easier for participants to grasp complex concepts or navigate intricate tasks. Moreover, we may introduce a **time delay** between the prompt and the participant's response to allow them more time for thoughtful consideration, accommodating their individual pace and requirements, as recommended by Merrill (1992) [197]. For instance, in Case Study I, we utilized prompts to guide participants in understanding how to approach a 3D model effectively. In Case Study II, participants were encouraged to locate specific information on websites and applications with the assistance of prompts. When participants struggle to provide responses due to insufficient understanding, we adopt an incremental approach, breaking down the support into smaller and manageable steps. This technique allows facilitators to support the participants' understanding step by step, providing just enough assistance for them to accomplish a single task.

5. **Fading.** Fading, the gradual reduction of aid, is accomplished by adhering to specified rules: physical and gestural assistance is reduced, and verbal suggestions are limited. When utilizing an application, for example, the quantity and quality of physical prompts are gradually reduced. Case Study I – interacting with AR – illustrates a situation in which participants required physical instructions until they independently learned how to hold and point the smartphone at the QR code. The fading process was implemented by progressively minimizing physical assistance – for instance, transitioning from direct hand guidance to lighter touches on the elbow – and substituting them with verbal cues. Fading should be used only when necessary, skipping this stage if prompting must be repeated, or if the study is completed in a short session and fading is not utilized.

6. **Repeat if needed.** Repeat the process (items 3-4) of assessing understanding and supporting understanding through prompting by going one question or task at a time whenever needed. You can move to the next task if the participant already learned or you can proceed with your planned study.

The previous steps are essential to support people with intellectual disabilities during co-design. One example of scaffolding applied to Case Study I is depicted in Fig. 3.6. It is critical to document both successes and failures throughout the process. On the one hand, using a structured approach for carrying out the activity can aid in participant engagement. Collecting information about the scaffolds, on the other hand, can provide vital information about the participant's understanding and, as a result, can aid in interpreting their input.

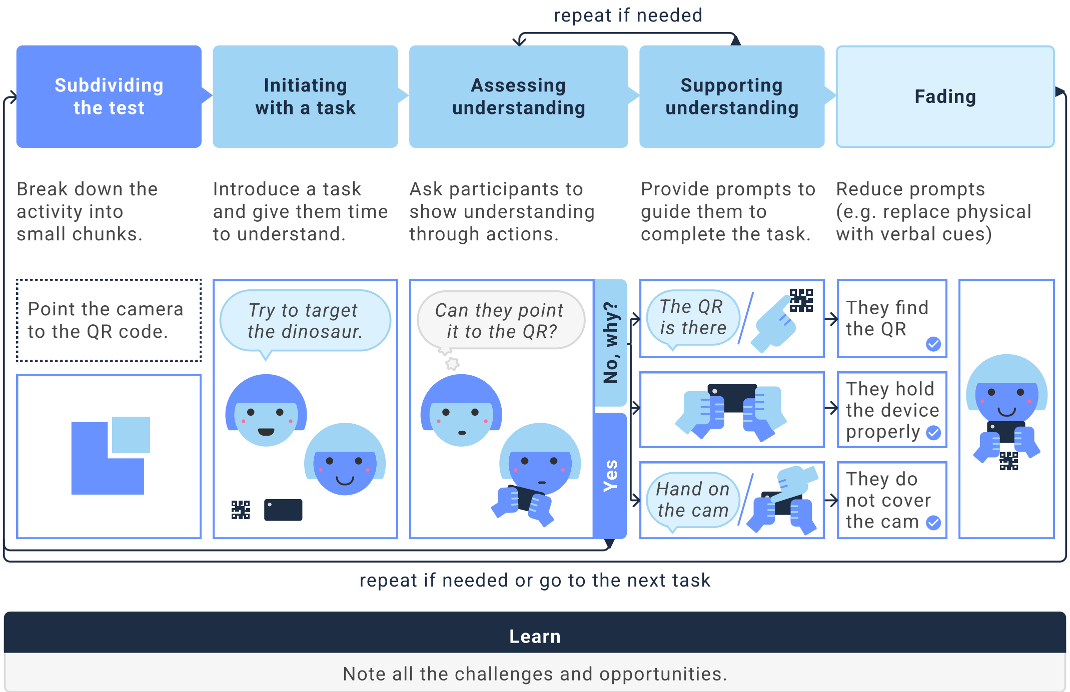


Figure 3.6. Scaffolding layers applied to Case Study I: AR interaction.

3.8.6 Discussing the Role of Scaffolding

We have defined the role of scaffolding in co-designing with people with intellectual disabilities and introduced case studies to demonstrate examples of scaffolding throughout the collaborative design cycle. We chose scaffolding for its research-backed effectiveness [24] and alignment with Applied Behavioral Analysis [173]. Unlike Cooperative learning [148], which emphasizes group activities, scaffolding offers tailored support. This method suits learners with intellectual disabilities, providing gradual learning through explicit instructions and support, ensuring individualized assistance for effective task performance.

Scaffolding not only assists participants in immediate task completion but also plays a crucial role in identifying the kinds of support that participants need, which can inform the design of more intuitive and accessible future technology iterations. By understanding how participants interact with technology with the aid of scaffolding, designers can anticipate user needs in later versions of the technology, enhancing users' ability to operate independently.

The first Case Study (Section 3.8.3), a hands-on experience, highlighted areas for advancement in AR technology and device sensors, surfacing the need for a sensor to detect when the camera is being obstructed and a tutorial on how to approach and downscale an object. It also helped us realize the importance of (1) establishing a good personal relationship with our participants and (2) how crucial it was to provide detailed instructions for conducting the proposed tasks, not only verbally but also physically – accompanying the verbal cues with physical gestures. Another important element that emerged was that each participant needed a different level of scaffolding related to their physical and cognitive needs, interest, and their level of engagement with the task. This amount of care paid out in the quality of the feedback we collected, enabling us to redesign the application.

In our second Case Study (Section 3.8.4), we co-designed a museum application that displayed complementary museum content. We used scaffolding to assist participants in eliciting prior information and completing the suggested activities, helping us to iterate the design of the application based on their invaluable feedback. We also gave them several forms of cues, drawing their attention vocally and pointing gestures to labels, numbers, letters, and icons as clues to help them on tasks. When eliciting prior information, we underscored the importance of understanding how participants approach tasks and access information, necessitating scaffolding techniques to redirect participants' focus toward the relevant content. The ability to use verbal and gestural scaffolding effectively not only supported participants in completing tasks but also empowered them. We recognized that encouragement and praise for accomplishments helped participants to complete their tasks with confidence. Finally, the study's findings highlighted the importance of scaffolding, self-efficacy acknowledgment, and effective communication channels in creating technology solutions that make museums more inclusive and enjoyable for all.

By scaffolding the session, participants were better equipped to engage with the technology and offer meaningful feedback. Fading the session gradually, allowed participants to gain confidence and independence in their interactions with the technology. By implementing these adjustments, we created an inclusive research environment where participants felt valued, heard, and empowered to provide valuable feedback. Moreover, when the same participants are involved over time, as in Case Study II, scaffolding can help to exchange and consequentially acquire new knowledge and skills. This contributed to the success of our research outcomes, as we were able to gather rich observations and insights that informed the development of more accessible and user-friendly technologies.

Additionally, the scaffolding strategy emphasizes the provision of temporary, adjustable, and tailored support for learning and engagement in co-design activities [318][39]. This strategy recognizes the unique requirements of individuals with intellectual disabilities and the need to differentiate assistance based on their specific needs and abilities [237]. By collaborating with professionals who work closely with them, we gain valuable insights into the specific challenges and strengths of each participant. Scaffolding acknowledges these challenges and incorporates strategies to reduce cognitive load, such as breaking down information into smaller, manageable chunks and providing ample time for participants to respond.

It is important to point out that a balance and a trade-off exist between providing scaffolding by prompting, allowing users to understand independently, and figuring out how to complete tasks across the stated case studies. Following educators' advice, we provided detailed instructions that were often tailored on the fly [277] in a reflection-in-action process [318] to fit the participants' specific abilities and needs. This strategy enabled us to adapt tasks, both in terms of presentation and overall complexity, to suit the different needs and abilities of the participants. Given it was their first exposure to the presented technology, we wanted to avoid them feeling lost and frustrated by the lack of guidance. Instead, we provided encouragement and support to maintain their engagement when performing the proposed tasks. However, it is important to notice that this happens during the co-design process, where it is essential to facilitate and guide the use of technology. The same strategy would not be appropriate when running a formal summative evaluation session.

3.8.7 Limitations and Future Work

Further research is needed to validate and refine these guidelines with participants with a diverse range of disabilities and note their effectiveness for research on various technologies. Another limitation is that with scaffolding comes researcher discretion and variability around what the 'prompting' might be. An area for future work is systematizing the prompting to make it more consistent across conditions. Finally, a last limitation is that more work needs to be done to understand the repercussions of focus group scaffolding when more than one participant is present, and the abilities and scaffolding necessary to move to the next layer of information are not consistent across participants.

Areas for future work involve testing and refining the guidelines and related steps with a wider spectrum of intellectual disabilities, with more than one participant present (as in a focus group), and with a varied and diverse range of technologies. Future work can further inquire into how to include and actively involve different players in our research, such as educators and clinicians, to promote their engagement while drawing from their areas of expertise, knowledge, and skills. Additionally, more research may also explore and consider ways to empower the role of participant caretakers, educators, and assistants in co-design as this research continues to inform how we might help scaffold understanding and co-create technologies that are more accessible.

3.8.8 Conclusions

The voices of people with intellectual disabilities can be amplified in research by enabling them to participate actively and make contributions. Scaffolding co-design sessions is one of the means to improve their participant, however, it lacked a systematized structure for its use. We found that scaffolding in co-design serves as a means of empowering individuals, enabling them to become more independent over time. As participants gain new skills and confidence, they can better contribute to the design process. Furthermore, scaffolding in co-design sessions fosters a reciprocal relationship where participants gain not just experience with the technology but also a sense of accomplishment and self-actualization. By actively engaging participants and respecting their contributions, we enhance the design process and promote their personal growth and self-efficacy. Moreover, we cultivate more active and engaged participants who can provide valuable input. This approach improves the immediate outcomes of the co-design process and offers long-lasting benefits as individuals develop their abilities and become more self-reliant contributors to technology design while acquiring essential digital skills.

3.9 Supporting Participatory Design

Participatory Design is a multifaceted approach integrating individuals with intellectual disabilities into the design process. This strategy ensures that developed solutions are accessible and deeply resonate with users' personal experiences and preferences that are grounded in Participatory Design, scaffolding, improvisation, alternative communication methods, and the nuanced involvement of caregivers [39, 68]. At the core of Participatory Design is its political roots, advocating for the active involvement of individuals with intellectual disabilities in creating technological solutions [33, 282]. This engagement ensures the development of meaningful and empowering solutions, tailored to users' needs and preferences [132].

Our participants proved to be very different from each other, with different needs as well. Thus, the whole research became less pre-defined and more open to adapting to each of them. Scaffolding strategies provided tailored support to facilitate effective participation in the design process, offering adjustable levels of assistance to enhance understanding and engagement [324]. This strategy supports participants in contributing meaningfully to the development of technological solutions, ensuring their voices are heard and valued, with the option of abandoning a task if that proved frustrating (e.g., finding a word when the font size was not big enough).

This research took an unorthodox path as dealing with different museums and associations brought up many practical obstacles. Improvisation was crucial for accommodating the unique needs and preferences of participants, allowing for the flexible adaptation of design processes and solutions based on direct feedback [105, 167]. This dynamic aspect of the methodology encourages creativity and flexibility, fostering innovative solutions that might not have been considered in a more rigid design framework.

Recognizing the diverse communication needs of individuals with intellectual disabilities, the methodology incorporates a variety of alternative communication methods [170], including AAC and drawings. The alternative communication methods not only aided our participants with intellectual disabilities but also could improve the experience of different groups of people, such as those who are illiterate. Illiterate participants would not understand the written text but could benefit from pictograms (understanding the content by looking at pictograms) or through the text-to-speech features. Participants could feel free to participate in their own ways, ensuring a deeper and more accurate understanding of their perspectives.

Further, educators and support workers play an instrumental role in providing insights into the needs and preferences of individuals with intellectual disabilities. However, distinguishing their perspectives from those of the participants ensures the final designs authentically reflect the desires and aspirations of users [132]. Using scaffolding and improvisation, we could mitigate this influence by focusing on the participant rather than on hearing their perspective by proxy.

Enriching participatory design with scaffolding strategies, improvisation, AAC, and the careful involvement of caregivers, we involved individuals with intellectual disabilities in the design of technological solutions. The upcoming sections delve deeper into improvisation and scaffolding, with an emphasis on methodology. This includes two case studies on AR and ACCESS+, setting the stage for future chapters focused on co-design and accessibility features.

3.10 Conclusions

The chapter addressed the emerging trends in involving individuals with intellectual disabilities in the participatory design of digital and interactive prototypes. It emphasizes a methodology that prioritizes the unique needs, preferences, and abilities of people with intellectual disabilities, leveraging ICT to create accessible, engaging, and empowering experiences. The adaption of participatory design is central to this approach, as it advocates for the active participation of individuals with intellectual disabilities in the design and development process.

This narrative set the stage for addressing the methodological research question: "How can we design technologies that are both inclusive of and effective for people with intellectual disabilities?". At this point, RQ 1.1 offers preliminary insights, while RQ 1.2 and 1.3 are linked to the proof of concept that will be elaborated upon in the discussion, after expanding on Part II and III.

The chapter provides a structured response to RQ 1.1: "How can we involve people with intellectual disabilities in Participatory Design?" The synthesis of the conducted studies and literature review offers several key strategies:

- **Adapting Design Methods**: Traditional HCI techniques often rely on verbal communication and abstract reasoning, and may not suit every participant. Adapting these methods to meet the specific needs of individuals with intellectual disabilities is a critical consideration in participatory design.

- **Adoption of Co-Design Methodology**: Anchoring the methodology in Participatory Design ensures the active engagement of individuals with intellectual disabilities throughout the design and development processes. Using this approach we guarantee that the technologies created are not only accessible but are deeply aligned with the users' experiences and preferences.

- **Use of Scaffolding Strategies**: Utilizing scaffolding strategies that offer temporary and adaptable support accommodates the varied needs of individuals with intellectual disabilities. This strategy allows for a higher comprehension of tasks, ensuring that participants can engage meaningfully in the design process.

- **Emphasis on Improvisation**: The flexible and spontaneous adjustment of the design process, based on the direct needs of individuals with intellectual disabilities, underscores the significance of improvisation. This adaptability encourages innovation and creativity in accommodating diverse needs and preferences.

- **Incorporation of Alternative Communication Methods**: Acknowledging the diverse communication needs of individuals with intellectual disabilities, the methodology integrates various communication modalities, ensuring a comprehensive understanding and inclusion of the participants' voices and perspectives in the design process.

- **Involvement of Caregivers**: While caregivers offer essential support and insights into the preferences and needs of individuals with intellectual disabilities, it is crucial to differentiate their views from those of the individuals themselves, ensuring that the final designs authentically reflect the users' desires and aspirations.

As the discussion progresses into Part II, Digital and Interactive Technologies, the conclusions drawn from this chapter underline the importance of active participation, scaffolding, and improvisation in the participatory design process with individuals with intellectual disabilities. This methodology ensure that the resulting technologies are accessible and meaningful to the users, fostering a sense of belonging and engagement while accommodating their diverse needs through flexible and adaptive research and design methods.

Part II

Digital and Interactive Technologies

4

Augmented Reality

This chapter opens the Part II of my doctoral dissertation, and it is based on a project that predates my PhD studies. It is one of the chapters that provide content to answer RQ 1.2 (*How can we involve people with intellectual disabilities in the evaluation of digital and interactive prototypes for museum visits?*) and to address RQ 2.1 (*How does the use of augmented reality influence the access to and engagement with museum content for individuals with intellectual disabilities?*). My initial AR project aimed at making learning accessible to everyone, regardless of their location or social status, by utilizing QR codes for their simplicity and effectiveness in low-light conditions.

I expanded upon my previous experience with a focus on enhancing accessibility features for individuals with intellectual disabilities. The COVID-19 pandemic highlighted the importance of AR technology as a means of remotely exploring artworks and educational content, making it an invaluable tool in times when physical access to cultural and educational institutions is limited.

This work makes a significant contribution to HCI by shedding light on the preferences of users with intellectual disabilities when interacting with AR, demonstrating AR's potential for promoting independent learning and emphasizing the importance of participatory design practices in the development of inclusive and effective technology solutions. As we explore the design, methodology, and user experience within the museum content, this chapter emphasizes the power of augmented reality in making content more accessible and engaging for all.

4.1 Introduction

Technologies such as Augmented Reality are becoming more popular as compatible devices are widely available, impacting how we can, for instance, learn new content and have fun. Despite its positive impact on engagement and learning, this technology is still not widely investigated with an accessibility focus, considering its benefits and limitations. Methods to produce inclusive and accessible solutions, such as co-design sessions, are time-consuming and require the involvement of different stakeholders and researchers to play various roles. The complexity of the design process can impact how people with Intellectual Disabilities can interact and benefit from AR.

In this work, we assessed the interaction of people with intellectual disabilities with an AR application for informal learning. During three research visits, we organized focus groups to assess participants' previous knowledge and familiarity with the app's content. Then, we introduced the technology and collected their preferences. Later, we assessed their perception of AR elements with hands-on individual sessions. Finally, we went to the museum with them to contextualize the app and gather their preferences on the medium to be used during a visit.

Participants provided details about the size, color, and description of each 3D content. Participants did not have a precise preference for the realism of the 3D model, suggesting that incredible detail in the 3D model may not be necessary for the success of the AR application. Audio feedback and self-introduction provided a more immersive experience, while labels were less important but still provided an affordance. Some participants encountered issues with the device itself, highlighting the importance of adapting both the application and the device to ensure that software and hardware are accessible to users. Despite these challenges, participants quickly learned how to use AR technology to explore the model and became more confident in their ability to use the technology.

In this chapter, we contribute to the field of HCI in several ways. To begin, we provide insights into the preferences of users with intellectual disabilities interacting with AR, in terms of elements that should be considered during the design. Secondly, the study proved the potential of AR applications in engaging users independently in informal learning experiences, by giving them the possibility to interact and explore independently the learning content. Lastly, the involvement of participants in the iterations of the design process proved the importance of co-design practices and highlighted the roles they can take. By involving participants with intellectual disabilities, designers can have access to their unique experiences and needs, thus allowing the development of more accessible and effective solutions.

This chapter is organized as follows: Section 4.2 introduces the design of our AR prototype. Section 4.3 presents the methodology used in this work. Yet, Section 4.4 shows the results we collected. Section 4.5 presents a discussion focusing on our research questions. Then, Section 4.6 introduces guidelines. Section 4.7, the limitations and future work. Section 4.8 concludes this chapter. Lastly, a comprehensive exploration of AR for learning, accessible AR in museums, and designing accessible AR was already introduced in Section 2.6.

4.2 Designing AIMuseum: the AR prototype

The development of AIMuseum aimed to provide a solution for people with disabilities to access and interact with cultural environments with ease [122]. In this chapter, we are describing how we evaluated the usability of AIMuseum – the AR app – and discussing the implications of our findings.

The application was built using the Unity game engine and the C# programming language and utilized the Vuforia API. We used QR codes as markers in our application, as they are easily recognizable, even in low light conditions, due to their black and white design. The QR codes were optimized for our needs based on preliminary testing, and the size and quality were adjusted accordingly. Additionally, we integrated a Screen Reader accessibility feature, using a UI Accessibility Plugin for Unity.

We engaged with educators to fit the AIMuseum experience with the learning objectives of the participants and the contents of the local museum. As a result, the application displays natural science content, focusing on dinosaurs, crocodiles, wolves, and deer. Each item was represented by a 3D model, a descriptive label, and audio feedback that provided a self-description (Fig. 4.1). Except for the dinosaur fossil, all of the selected animals were present in the museum as taxidermied specimens.

To improve accessibility, the main menu includes a quick tutorial to help participants to use the application, and the possibility to change settings. The application interface uses a responsive UI design, adaptable to the user's device screen size – smartphone or tablet. Participants have the alternative to configure settings such as volume, font size, and language. The application UI can be found in Fig. 4.2. In Fig. 4.2a the main screen is available. Pressing Next, the user will find the instructions page, Fig. 4.2b. Finally, pressing on options, Fig. 4.2c, the settings will appear to personalize the app.

When the app is launched, the user simply needs to point their device at a QR code to get information about the animal. The application will scan the code and provide further information, in this case, a brief description of the animal. The user can hear this information if the screen reader is turned on.

We evaluated several characteristics together with the participants in an iterative process for each feature. In particular, we considered the 3D model realism,

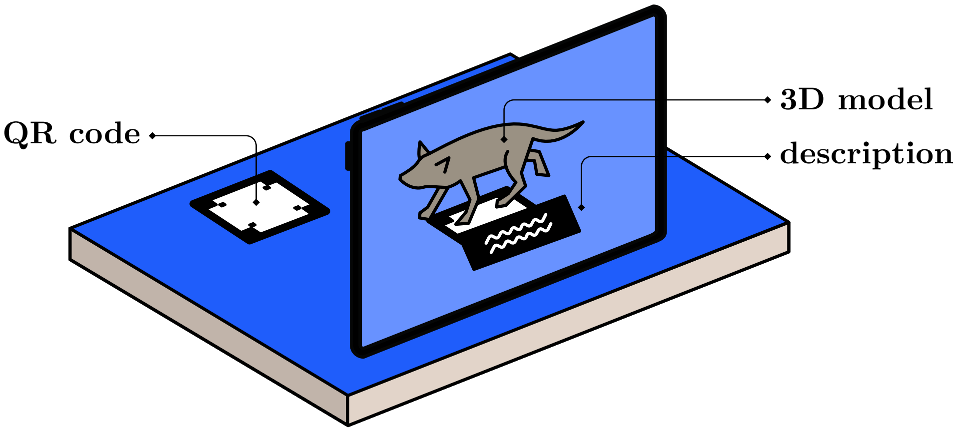
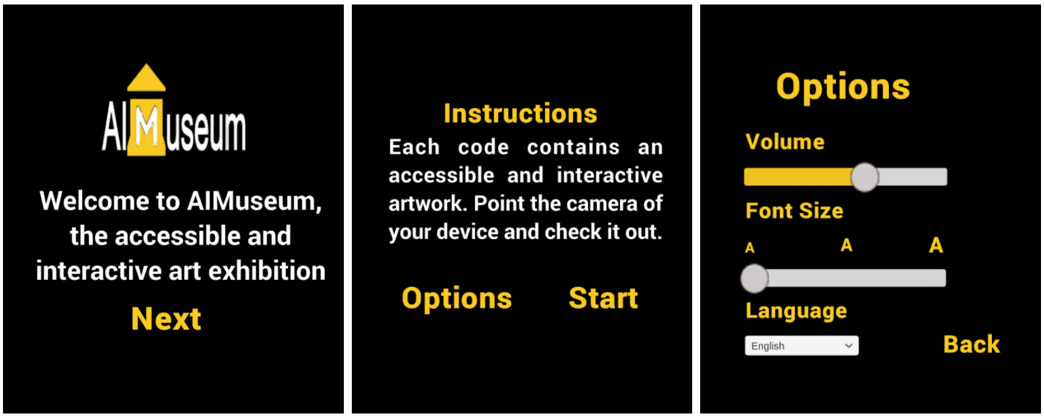


Figure 4.1. Illustration of how the AIMuseum application works: it reads a QR code and generates a 3D model and description of the museum content.



(a) Main Screen (b) Instructions (c) Settings

Figure 4.2. AIMuseum user interface.

size, and texture; textual description size, color, and background; voice (text-to-speech) regarding gender, tone, speed, and type.

4.3 Methodology

4.3.1 Rationale and research questions

This study assesses the accessibility of AR by people with intellectual disabilities when using assistive technologies before, during, and after a museum visit - an informal learning domain. While most AR research for intellectual disabilities has focused on formal education, little is known about its effectiveness in informal settings such as museums.

The research consists of a user study that seeks to understand how people with intellectual disabilities interact with AR and how they make sense of the information that it provides in the context of informal learning. We conducted three research visits (RV I, RV II, and RV III) to ANFFAS, an association that works with people with intellectual disabilities in Trieste, Italy. There, we investigated the following specific research questions:

- **RQ 1:** Which AR elements define the user's experience, and what characteristics of those elements are critical?
- **RQ 2:** How simple is learning and remembering how to interact with AR?
- **RQ 3:** What roles do participants play in the co-design of an AR application?

4.3.2 Procedure overview

To develop the procedure, we collaborated with ANFFAS. The research fit in with their daily learning activities and with their visits of museums and art galleries. The study was made possible by an agreement between the participant's association and the research organizations involved. With the participants' and/or guardians' consent, we did not store any sensitive information, only audio and video for data analysis.

Over three visits, lasting a total of nine days, we engaged with individuals with mild to severe intellectual disabilities to understand their needs and preferences for an AR application. We used a combination of activities and focus groups to gather their feedback and improving the app between visits (Fig. 4.3).

Our visits started with focus groups to get to know the participants and understand their prior knowledge about the animals we planned to introduce. The group discussed the animals through written responses or drawings, based on the participant's abilities, and we reviewed the key details about each animal

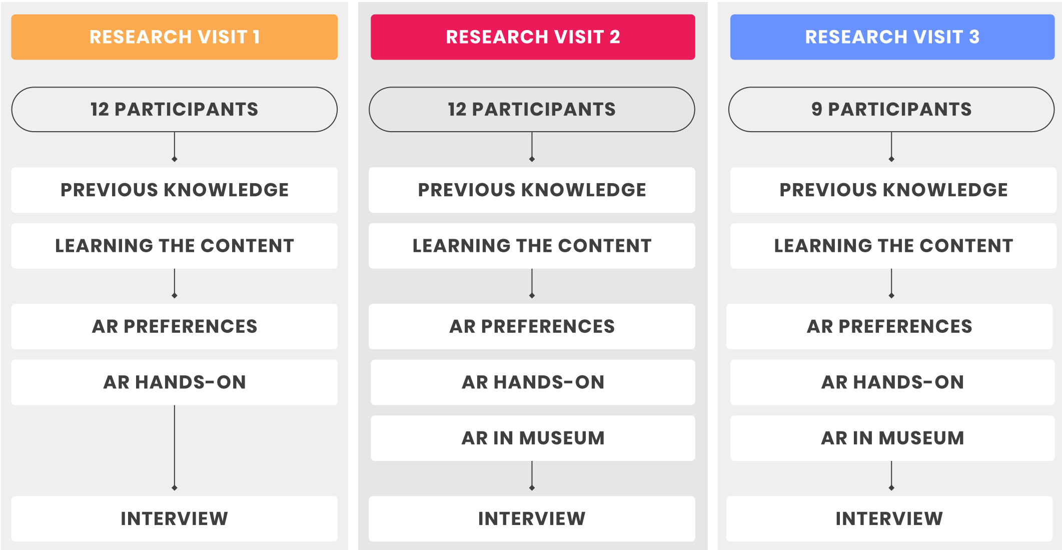


Figure 4.3. The procedure of the three research visits presented in this chapter.

with an easy-to-read text. We used easy-to-read guidelines also in the context of interviews and oral communications [214]. During the study, we asked questions to assess their technology habits and preferences.

On each visit we evaluated the AR app with the participants, first introducing AIMuseum at the association. On the first visit, due to COVID-19 restrictions, participants couldn't go to the museum. Without directly interacting with the device, we showed them how AIMuseum worked and we asked them about the size and color of the text, and about the audio feedback parameters, such as the voice's tone, speed, and type (human or synthesized). We also asked about their preferred interaction method. A few participants did a hands-on pilot test. During the second and third visits, all participants directly interacted with the app on a tablet and gave their thoughts on what they saw and heard. On the second visit, we also presented 3D models with different textures, ranging from realistic to minimal, to gather their preferences.

On the second and third visits, participants were given the opportunity to explore AIMuseum in the museum we collaborated with – The Civic Museum of Natural History of Trieste, Italy. Participants were given 10 minutes to freely use the app, while looking at the full-size animal model provided by the museum. To better understand their preferred method of learning about the animals, we offered three options during the second visit (easy-to-read text, AAC text, and AIMuseum), and five methods during the third visit (easy-to-read text, AAC text, AIMuseum, tablet with ACCESS+, an accessible app for museums [275], and a multisensory experiences box).

Finally, after each user evaluation session, we conducted individual interviews with each participant to assess retention and gather additional feedback. Participants were asked to recall their experiences and share their likes and dislikes.

We collected the data using annotations, pictures, and video recordings. The data were analyzed by the researchers to identify emerging themes to be discussed. We used a Miro board to map the results and clustered themes in different and relevant categories for each research visit.

4.3.3 Participants

This study involved 20 participants who were all members of the ANFFAS association in Trieste, Italy. The participants are all adults, ranging from 21 to 63 years old, with 13 women and 7 men (Table 4.1). Only 5 participants attended all research visits.

Prior to the in-person visits, the researchers met with the participants via video call to get to know them and make them feel at ease with the research goal and process. Following that, participants and their legal guardians were asked to give permission to take part in the study. During the visits, we emphasized that they could opt out at any time, and we reiterated the study's goal. The activities were kept short and breaks were included to ensure their comfort. The researchers were able to provide adequate time between sessions thanks to the assistance of educators who knew the participants.

At the third research visit (RV3), 12 participants were present. P22 and P9, who had recently recovered from COVID-19, joined online from a separate room. P10 attended fully online and was shown how AR works through a video call. P10, P12, and P13 also contributed with drawings during the third research visit. During the fourth research visit (RV4), 6 new participants joined and 6 participants from the previous visit were not available. Out of the 12 participants present, 9 went to the museum visit (P6, P8, P13, P15, P16, P18, P19, P20, and P21). Finally, on the fifth research visit (RV5), 18 participants previously attended one or both of our sessions, while 2 new participants joined. All of the 12 participants also went to the museum with us.

Table 4.1. Participants' demographic and research context information.

PID	Gender	Age	Research Visit	Presence	Context
P6	Woman	20-25	RV3 to RV5	In Person	Association and Museum
P7	Woman	40-45	RV3 to RV5	In Person	Association
P8	Man	30-35	RV3 to RV5	In Person	Association and Museum
P9	Man	60-65	RV3	In Person	Association
P10	Woman	30-35	RV3	Online	Association
P11	Woman	50-55	RV3 and RV5	Hybrid	Association
P12	Woman	50-55	RV3	Hybrid	Association
P13	Woman	20-25	RV3 and RV4	In Person	Association and Museum
P14	Woman	20-25	RV4	In Person	Association
P15	Woman	50-55	RV4 and RV5	In Person	Association and Museum
P16	Woman	60-65	RV3 to RV5	In Person	Association and Museum
P17	Man	25-30	RV3	In Person	Association
P18	Woman	45-50	RV4 and RV5	In Person	Association and Museum
P19	Man	50-55	RV4 and RV5	In Person	Association and Museum
P20	Man	45-50	RV3 to RV5	In Person	Association and Museum
P21	Man	55-60	RV4 and RV5	In Person	Association and Museum
P22	Woman	45-50	RV3	In Person	Association
P23	Man	20-25	RV4	In Person	Association
P24	Woman	50-55	RV5	In Person	Association
P25	Woman	55-60	RV5	In Person	Association

4.4 Results

4.4.1 User evaluation at the association

Previous knowledge and learning the content.

On the first steps of each research visit – previous knowledge and learning the content – we made our participants free to express their ideas in the best suitable way, by writing, drawing, or simply speaking out loud (Fig. 4.4). Everyone was encouraged to participate. Each correct answer was followed by positive feedback from the educator, stimulating participants to keep engaged.

We used the whiteboard to put participants' contributions related to questions such as: What do you remember about the animal?; What characteristics did it have?; Where does it live? The questions slightly changed to adapt to users' needs and museum content. During the activity, the researchers were helping the ed-

(a) Group discussion (b) Dinosaur content drawings

Figure 4.4. Conducting the previous knowledge and learning the content sessions.

ucator and familiarizing themselves with the participants, including the analysis of their roles and contribution to the group discussion. Personality and abilities played an important role in participants' discussions: verbal and talkative participants always wanted to contribute. The educator managed the participation to achieve everyone's full potential, with collaboration from everyone and scaffolding whenever needed (prompting questions and fading when they achieved the goal).

First steps.

Most participants interacted with AR for the first time and needed help to start the activity. P7 looked at the screen and, when she started touching the tablet, said: "*Help, how do I do it?*". On the other hand, P6 was so happy and proud of knowing how to complete tasks and interact with the device and the application. She also remembered details of the interface in the following RVs, including the label and its volume icon. Besides, some participants such as P6 demonstrated great independence during our sessions: "And we can start, so I will start now."

Emotions.

We noticed several verbal and non-verbal emotional expressions during our work, from surprise to indifference, happiness to fear. The contents, mainly concerning the dinosaur and the crocodile, were not the most helpful in avoiding making some participants afraid. When we asked P7 if she was scared, she said: "*A bit. I mean, almost not, because the crocodile is far away*". P20 said when the audio played: "*Wow, how do you do this?*". This magical feedback was met with fun and engagement. On the other hand, some participants were puzzled, confused, or afraid of the content. The more they got comfortable with the application and us, the more they participated.

P15 recognized the crocodile and made a disgusted face saying: "I won't touch it; it's disgusting; I don't like crocodiles." When we asked if she would have preferred to see a dog, she answered: "Yes, a dog yes, but not a crocodile." In the case of P6, the fear was also mixed with surprise and amusement: "Oh gosh, amazing! But it made me a bit scared!" P19 was nervous during our AR evaluation session; he held the tablet and shook his hands. We believe this is because he feared dropping and ruining the device.

Interaction.

We noticed difficulties related to dimensions and distances in AR. We asked participants to zoom in on some characteristics of the animal, such as teeth, legs, and tail. Participants brought the smartphone closer to themselves rather than the animal. Likewise, when asked to zoom out, the same issue arose. When using the phone to explore the virtual object, we noted a problem with rotating the device. The difficulty increased for P9, who is in a wheelchair with reduced space for mobility. Another challenge of using the smartphone is related to the position of participants' fingers, as sometimes they unconsciously block the camera and missed the AR experience.

The device's size plays an important role. In the experiment we ran during the fourth research visit, we used a tablet to provide a bigger screen size and avoid the fingers easily being placed over the cameras. Both devices have pros and cons since a tablet is heavier and harder to hold. It is also essential to have a QR code well positioned to avoid confusion. P21 was, on both research visits, swiping the QR code on the tablet instead of holding the device. Similar to what we do when swiping a card for payment. The QR code was also associated with previous experiences: P16 associated the QR code with a COVID-19 pass and P7 with a photocopy.

Feedback provided by participants on the overall experience proved meaningful too. P10 said, "*It's a good idea for someone who can't read*" and P16 was surprised, "Let's say it must be screen magic."

Audio: gender, speed, type and content.

During all research visits, we associated each QR code with a 3D model, a label providing its description, and audio feedback with a self-introduction of the content with different parameters, changing the gender to man/woman, the speed to faster/slower, and the type to synthesized/humanized. The dinosaurs said, “Hi, I am a dinosaur” (brown) or “Hi, I am another type of dinosaur” (white), while the crocodiles “Hi, I am the Nile crocodile, and I live in some regions of Africa” (realistic texture) and “Hi, I am another type of crocodile” (light green). We chose to have the animals self-introduce themselves to evaluate the participants’ approval of text-to-speech technology and provide an alternative way to understand the text for non-literate participants.

In general, they appreciated having the audio feedback. When we asked, “What would you do if a digital dinosaur/crocodile talked to you?”, P7 said, “*I would say: Hi, I’m P7*”; P8 said, “*Oh gosh, no*”; P20 said “*Makes me a bit scared. If it is a cute animal, ok, but a big one, no*”; and P17 said, “*It is weird, but I like when it talks*”. When we tested the voice with different parameters, gender was indifferent to 72% of the participants, while 28% preferred a masculine voice. Most participants could notice when we changed the voice. 28% of the participants preferred a faster, 14% a slower voice, and 58% were indifferent about this aspect. The voice type seems not to get a consensus: 44% preferred a synthesized voice, 28% a humanized voice, and 28% were indifferent. When we asked specifically about the voices, we heard from P16 that “The voices were slow, they were not the clearest, but I could understand the words”, and from P18, “The voices were so sweet.”

Content: size, labels, and appearance.

We asked our participants about the size of the 3D objects, comparing across versions, with one about 25% smaller than the other. Almost all of the participants noticed the first one was bigger. Specifically, P7 said, “*Yes, I noticed the difference. That other one was big, and this one was small*”, and made gestures with her hands to represent the size. When we asked what size they preferred, 28% of the participants were indifferent, while 44% preferred the bigger version and 28% the smaller.

We designed some 3D models with different colors. The dinosaur was available in white or brown, while the crocodile was in light green or with a realistic texture (Fig. 4.5). Analyzing the results of the third research visit, we found out that 72% preferred the brown dinosaur, while 14% picked the entire white, and

14% did not have any preference. P11 said she saw a plastic dinosaur, referring to the white version.

For the crocodile model, we first introduced the realistic texture (Fig. 4.5b) and later the light green color (Fig. 4.5a). After that, we asked if the second crocodile was different and how. 75% of the participants associated the first one with the real one, 17% thought the second was real, and 8% did not have an answer. P17 said "*The last one was fake*".

4.4.2 User evaluation at the museum

(a) Light green crocodile (b) Realistically textured crocodile

Figure 4.5. Museum visit: participants interacting with the content 3D model.

We focused on participants' preferences when learning about the museum content during the museum visits (Table 4.1).

On the fourth research visit, we asked them to choose between AAC text, easy-to-read text, and AIMuseum. AIMuseum was chosen as the first choice by 4 participants. When it was not the first choice, it was the second choice of 4 other participants. It is also important to mention that the AAC text was the primary choice of the other 5 participants. The easy-to-read text was not the first choice of any of the participants. Only P15 didn't choose the tablet between the main choices. She said she had never used a tablet before and disliked technology. This participant often avoided our proposed activities, so we respected her decision to do not proceed with a specific session.

On the fifth research visit, we asked about their preferences between AAC text, easy-to-read text, AIMuseum, a multisensory experience box, and ACCESS+. All participants chose a high-tech solution as their first choice: 8 chose AR, and 4 chose ACCESS+. AIMuseum was the second choice for 2 participants, the third choice for one, and the last choice for one. One participant chose a low-tech solution as their first two choices.

4.4.3 Interviews

We interviewed participants individually after each user evaluation at the association and museum. We applied this method to analyze the retention from each activity, reinforcing what they remembered right after leaving the testing room and expressing their preferences.

On the third research visit to the institution, the educator asked our participants what the researchers showed them, and she provided more specific questions to trigger their memory if needed. Most of the participants could remember details of the dinosaurs. P11 said, "*It was a plastic dinosaur*", while P6 mentioned she saw "drawings with writings; they look like pictures made on a large white sheet; there was a dinosaur, you could see the body, the legs, the tail." P20 mentioned the dinosaur self-introducing was weird; it reminded him of 3D movies.

On the fourth research visit, questions were more specific about the crocodile model: What did the researcher show you?; What was the shape and color of the object?; Did the voice change, and what was the voice saying?; Did the text change, and what was written?; Could you interact with the application alone or did you need help?; Have you already seen any other animals with the researcher using the tablet? [to understand if they remembered the previous experience]; What did you like? What did you not like?. All of them could remind a crocodile as the animal they interacted with. Most of them also gave details about the 3D model: size, color, and voice. The label was not perceived as important; some participants could not read it. 7 participants could remember correctly details and order of interaction related to shape and color – surprising information given the complexity of the question. Most could also remember the sentences introduced with the audio.

When we asked if they needed help, most said they needed help to hold or control the tablet. P16 said, "*I knew how to do it alone, but sometimes I needed help*". We were also interested to know if they had a previous similar experience, and more than half of the participants could remember interacting with AR in our previous session. Most participants mentioned adjectives such as fun and beautiful to describe what they liked about the experience; on the other hand, about what they didn't like, most participants couldn't mention anything specific, while P6 mentioned the woman's voice and P13 the colors.

On the fifth research visit, we provided more general questions and questioned their level of independence: What did you do?; Did you have to do something by yourself?; Were you able to use the tablet alone?; What animals did you see?; Did you hear any noises?; and What was the experience like?. Ten participants answered the questions related to their experience interacting with the tablet. P6 said, "*I had to see the wolf and the big reindeer. You had to move the tablet over the writing on top of the black thing called a QR code*". And P19 mentioned, "It is a little scary because seeing it so big made me a bit tense. It was a surprise to see the animal." 4 participants mentioned that the interaction was easy and they could do it alone; 3 said it was difficult, and 2 needed help. P8 and P11 explained it was hard to focus on the QR code, and the content was "disappearing or running away"; they lost track of the tag and asked for help. Most participants were already familiar with the researchers; this time, some of them also mentioned having a lot of fun – highlighting the importance of the connection between researchers and participants.

During the museum visits, they had a follow-up individual interview to elicit extra feedback. We asked the 12 participants about what they experienced and which were their favorites. In particular, they recalled their interaction with the animal displayed by AIMuseum while mentioning the nearby stuffed animal, thus making the connection between virtual and real objects.

4.5 Discussion

It is important to emphasize the different roles each participant can play. Our 20 participants contributed differently to our co-design sessions; we could associate them as informants, evaluators, or designers. The emotions and contributions of stakeholders play an important role in any research involving people with intellectual disabilities. This study could have different outcomes for diverse marginalized and understudied communities.

4.5.1 3D models are the pivot point of the interaction

Most of the participants could provide details about the size, color, and voices of each 3D content. Most participants preferred realistic or colorful textures for the AR interaction. The size of the 3D content is also not a consensus – participants tended to favor the bigger versions, however, a bigger device, such as a tablet, could make them feel scared. This suggests that the interaction with the 3D models is the main touchpoint of the experience, prompting participants to engage with the digital content. However, despite the importance of the model, participants did not have a precise preference for the realism of the 3D model. This implies that incredible detail in the 3D model may not be necessary for the success of the AR application. Instead, the main goal of the AR app should be to provide an enhanced way of looking at the models, as visitors are often unable to freely move around items in the museum. It's also worth noting that the taxidermied animals in the museum can provide the necessary detail, while the AR app can focus on enhancing the experience by enabling visitors to interact with the models in new ways.

By providing audio feedback and self-introduction by the models, the AR app can provide a more immersive experience, catering to visitors who are non-literate or prefer audio feedback. Gender is not essential for audio content inside an AR application; the regular pace is preferred rather than a faster or slower speech speed; and audio type is not a consensus – we could go either with a human or synthesized voice. Lastly, the labels did not appear as important; participants were more interested in the 3D model characteristics. However, while the audio feedback was the preferred method of receiving information about the models, the label still provided an affordance that showed there was additional content beyond just the 3D model. Even though it was not as preferred as the audio feedback, having the label as a visual cue likely helped participants fully engage with the experience.

4.5.2 Interacting with AR is easy to learn and easy to remember

The study involved participants interacting with AR technology in three separate sessions over the course of a year. While not all participants were involved in every session, the majority participated in at least two sessions. The sessions were conducted months apart, allowing researchers to observe how well participants retained their ability to interact with the AR application.

The most common difficulty encountered by participants was related to movement around the model. Specifically, participants needed to move the tablet closer to the QR code to make the model appear larger on the screen. However, many participants believed they needed to move the tablet closer to their face to better see the model. This counterintuitive perception, which differs from their prior experiences of looking at images, is probably caused by the novelty of the encounter. In addition, some participants had issues with the device itself. For some, the smartphone was too small, making it easy to accidentally block the camera with their fingers. Conversely, the tablet was sometimes too heavy, requiring two hands to use. This shows the importance of adapting both the application and the device to ensure that software and hardware are accessible to users.

Despite these challenges, participants quickly learned how to use AR technology to explore the model. Over time, they required less help and became more confident in their ability to use the technology. Participants remembered how the QR code and the device interacted, allowing them to recall how to use the technology easily. Although some participants required a brief recap on how to explore the model (P16: "I knew how to do it alone, but sometimes I needed help"), it did not negatively impact their experience. AR technology is a usable and friendly tool for providing content in a new way. It does not need prolonged use too; it has the potential to be a powerful tool for engaging users and enhancing their learning experience.

4.5.3 Participants can act as informants, evaluators and designers

Collaboration and participation are critical components in developing usable and effective solutions, especially when designing for marginalized and understudied communities. Inclusive design practices aim to involve all stakeholders in the design process to ensure that the resulting solutions are usable and meet the needs of all users.

The value of the participation of people with intellectual disabilities is significant. As demonstrated by the results of the co-design sessions undertaken in this study, these individuals have unique insights into their experiences and needs, which can inform the design of solutions that are more accessible and effective. Additionally, the active participation of users with intellectual disabilities in the design process can help break down stereotypes and misconceptions about this community and empower them to shape their own experiences actively.

In the context of usability, during the co-design of this study, participants took on spontaneously different roles, such as informants, evaluators, and designers. As informants, participants provided valuable insights and feedback that can inform the design process. As evaluators, participants assessed the usability and effectiveness of the solution, identifying potential issues and areas for improvement. As designers, they were involved in the actual design process, providing input and ideas that shaped the solution through its iterations.

4.6 Guidelines

From the analysis and discussion of our data, we can extract a few guidelines to address the usability of AR-inclusive applications (G1 to G4) and guide their co-design (G5 to G8) with people with intellectual disabilities. In order to enhance the usability of inclusive AR applications:

- **G1**: Prepare QR-codes with different colors and sizes
- **G2**: Provide devices with different weights and screen sizes to accommodate participant's needs
- **G3**: Include AAC, text-to-speech, and easy-to-read texts or other strategies to facilitate participant's comprehension and involvement (e.g. Task Analysis)
- **G4**: Give choice to express the participants' creativity in their own way

When designing AR-inclusive applications for and with participants with intellectual disabilities:

- **G5**: Encourage different forms of expression and respect the pace and time for each participant to contribute and feel part of the process.
- **G6**: Prepare different questions and materials to adapt to participants' needs
- **G7**: Provide open questions to avoid the yes/no answer
- **G8**: Get to know your participants; they need to be comfortable before they can fully collaborate with you

This is not meant to be a complete list but just an initial step toward defining a flexible framework for designing inclusive applications.

4.7 Limitations and Future Work

The limitations of this work are primarily related to the context. At the association, we did not have a specific room to conduct the assessments, and we had to consider the influence of museums not being familiar places for the participants. Most participants could read and write, but not all of them. This impacted the interaction with labels and their preference for easy-to-read or AAC texts. Also, familiarity with technology was decisive in evaluating individual experiences. In future works, we plan to combine gamification with AR technology, helping participants to discover new content.

4.8 Conclusions

This chapter explored a study that focuses on improving the interaction between people with intellectual disabilities and AR applications. Our participants' rich feedback and insights were essential to co-design more inclusive and accessible technologies, and we extracted guidelines based on our findings to be shared with other researchers.

This study laid the groundwork for exploring RQ 1.2 and addressed RQ 2.1: "How does the use of augmented reality influence the access to and engagement with museum content for individuals with intellectual disabilities?". The response is summarized in several main points:

- **Enhanced Accessibility and Engagement**: The use of AR, as demonstrated by the AIMuseum application, significantly enhances access to and engagement with museum content for individuals with intellectual disabilities. Through the use of AR and QR codes, participants engaged with the museum's content in a more dynamic and immersive way. This approach made the educational content more accessible and captivating, as reflected in the participants' responses and feedback.

- **Preference for Audio Feedback and 3D Content**: Participants expressed a preference for audio feedback and detailed descriptions provided by the AR application. It suggests that auditory elements and interactive 3D models play a crucial role in enhancing the digital museum experience for individuals with intellectual disabilities. The study found that the realism of the 3D model may not be as critical as its ability to engage and inform the user.

- **Learning and Usability**: The study demonstrated that AR technology is not only engaging but also easy to learn and use for individuals with intellectual disabilities. Despite initial difficulties with device handling and understanding AR concepts, participants quickly adapted and showed significant interest and confidence in using the technology. This ease of use is crucial for the successful adoption of AR in educational and cultural contexts.

- **Emotional Engagement and Personalized Experience**: The AR application generated a range of emotional responses, from excitement and surprise to fear and discomfort, depending on the content. This highlights the significance of customizing the AR experience to each individual's preferences, needs, and comfort levels. A tailored approach can increase engagement and positive emotional responses, thus improving the overall experience.

This research opens the possibility of designing new AR applications for museums and suggests different factors influencing how people with intellectual disabilities use AR. It is essential to involve users in the design process, tailor the content to their preferences, and consider the usability and emotional impact of the technology to fully realize its potential. The insights from this research contribute to a broader understanding of how AR can be used to enhance museum visits for individuals with intellectual disabilities, offering a foundation for future explorations in this field. The following chapter, Accessible Applications will continue the exploration of Digital and Interactive Technologies by analyzing the design and iterative development of a museum application.

5

Accessible Applications

The choice to focus on making applications accessible was a natural extension of our inclusive design efforts, especially when considering the broader context of AR and the existing infrastructure participants had access to, such as a museum website with accessible content and a museum app. This decision was based on the recognition that applications are not only widely available but also have the potential to significantly improve the UX when designed with accessibility in mind. The inclusion of accessible features caters to the needs of people with intellectual disabilities and improves the overall design quality, making these applications more intuitive and user-friendly for a broader audience.

The application, ACCESS+, was initially utilized in Italy with content related to the Natural Science Museum, which is the focus of this chapter. The application was later adapted for use in Australia with the QUT Art Museum content, together with studies on museum artworks with social robots and inspiring themselves to use creative expression, these content will be presented in Chapters 6 and 9.

This is the second chapter of Part II of this doctoral dissertation. It is one of the chapters that provide content to answer RQ 1.2 (*How can we involve people with intellectual disabilities in the evaluation of digital and interactive prototypes for museum visits?*) and to address RQ 2.2 (*How does the use of accessible applications influence the access to and engagement with museum content for individuals with intellectual disabilities?*). This chapter makes significant contributions to HCI by providing useful insights into the design and exploration of digital and interactive technologies with and for people with intellectual disabilities and emphasizes the importance of co-designing inclusive applications that promote independence and participation. This study also includes stakeholders from various disciplines.

5.1 Introduction

Co-designing inclusive applications that cater to the unique needs and preferences of people with intellectual disabilities has the potential to support their independence and engagement in a variety of contexts, including cultural heritage sites such as museums. Yet, creating inclusive applications that are genuinely accessible and usable requires a collaborative and participatory approach that involves individuals with intellectual disabilities as well as relevant stakeholders, such as museum professionals, educators, psychologists, and technology experts.

People with intellectual disabilities face numerous barriers to accessing and fully participating in museums [187, 207]. Regardless, there is growing recognition of the importance of their inclusion and participation in these spaces. Inclusive and accessible applications represent a promising solution to address some of the challenges this population faces in museums. Such applications can provide tailored support, promote independence and engagement, and enhance the overall museum experience.

This chapter focuses on the initial design, heuristic evaluation, and co-design process of ACCESS+ [275], an accessible application designed with and for People with intellectual disabilities to navigate museum content. The first version was developed during the COVID-19 pandemic and required virtual participation from specialists and participants. When the barriers were lifted, we could meet participants and proceed with the co-design sessions. To iterate and make ACCESS+ more accessible, the co-design process involved multiple research visits with stakeholders (museum professionals, educators, psychologists, and technology experts) and individuals with intellectual disabilities to understand their needs and collect requirements.

The co-design process focused on customized and inclusive features, allowing users to adapt icon and text sizes, backgrounds, labels, and voices to their requirements and preferences. To help participants with different needs to make sense of the content, they could use Augmentative and Alternative Communication (AAC) pictograms of texts translated in plain language (Easy-to-Read) and listen to full-text text-to-speech (TTS) with a personalized tone, pitch, and highlight settings.

Through a qualitative approach, participants shared their thoughts in multiple forms, and the research aimed to gain insights into the participants' experiences with existing websites and applications, their understanding of user interface (UI) elements, and their overall user experience (UX), including challenges with specific features and touch-based interaction. This process involved multiple stages, such as brainstorming, focus groups, prototyping, and testing (hands-on and interviews), following principles of universal design, user-centered design, and participatory design.

Our qualitative approach aims to:

- **(i)** understand the overall experience with an existing museum website and application;
- **(ii)** gather the understanding of specific UI elements; and
- **(iii)** assess the overall UX provided by the new app, including the challenges with specific features and the touch-based interaction.

This chapter contributes to the field of inclusive design by providing insights into the co-design process of an inclusive application for people with intellectual disabilities in museums. Additionally, it offers practical recommendations for improving accessibility and usability, which can inform the design of future inclusive applications.

Finally, this chapter is organized as follows: Section 5.2 covers the initial design and collaboration with stakeholders, followed by heuristic evaluation and redesign efforts in Section 5.3. The co-design process, involving research visits and participant engagement, is detailed in Section 5.4. Findings from usability studies and participant feedback are presented in Section 5.5, leading to discussions on the co-design approach, inclusivity considerations, and future research directions in Section 5.6. The chapter concludes in Section 5.7 with a summary of key insights and the importance of accessible design in museum applications for users with intellectual disabilities. Lastly, a comprehensive exploration of accessible solutions designed for inclusion, communication, and reading was already introduced in Section 2.5.

5.2 Designing an Accessible Museum Application

The ACCESS+ application seeks to enhance access to the museum content with an accessible solution designed with people with intellectual disabilities in mind.

We collaborated with Anffas, an association that supports individuals with intellectual disabilities. and the Natural History Museum of Trieste - Italy. This collaboration seamlessly integrated into the participants' daily learning activities and museum visits, where they delve into the fascinating world of animals and assume the role of easy-to-read experts. Their task involved simplifying texts that were connected to the museum's content, making it more accessible to everyone.

We had several meetings with experts and participants to define the application requirements. The participants are adults with intellectual disabilities. We conducted online meetings and in-person research visits during 2021 to acquire empirical knowledge and develop closer contact with the participants. This long-lasting experience made us realize that several user interface elements are not intuitive for people with intellectual disabilities.

In partnership with the museum, we designed ACCESS+. We developed the current content of the application in two different languages (English and Italian). However, we present only the English version here to keep it consistent with the doctoral dissertation language. For research purposes, the application content was limited to the topics the participants were learning and could further appreciate in guided visits. The application in its first version includes already several features that could help people with intellectual disabilities during their interactions.

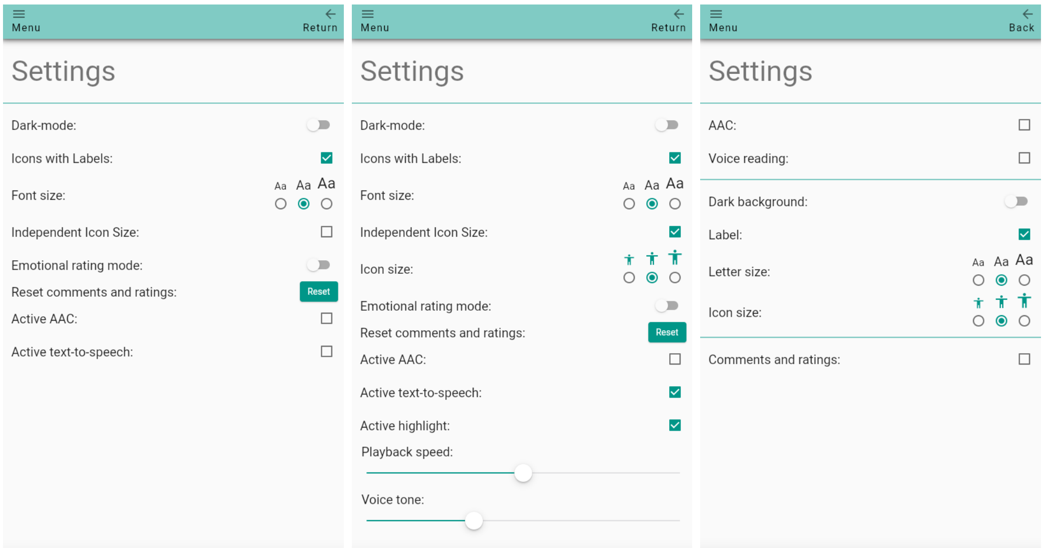
When designing the ACCESS+, we aimed for a simple, consistent, and customizable design [78][183]. We used conventional mobile application designs (e.g., top bar, burger menu icon, left side menu list) to structure the content. We wanted the application to be similar and consistent to what the users might have already seen/used or may see/use in the future. Regarding fonts, spacing, colors, and dimensions, we referenced the WCAG 2.1 and other W3C/WAI guidelines [305].

We developed ACCESS+ using an open-source UI software development kit called Flutter [112]. This choice allowed us to develop a cross-platform application, in particular, we wanted to be able to deploy for Android, iOS, and the web. Moreover, the application design is responsive so that we can easily use it on mobile, tablet, and desktops. All those technical decisions have been made in order to have a coherent design among different platforms and screen sizes.

We implemented a variety of customizations to allow participants to adapt the interface to their needs (Figures 5.1a, 5.1b, 5.1c).

- **Light and Dark modes**. Both modalities have a high contrast between background and text and background and accent color. We limited the range of colors to three (background, text, and accent) for simplicity matters. Except for the emotional rating icons coloring (we will explain the reason below).

- **Three size options**. It is possible to enlarge or reduce the size of the text and icons (together or independently) according to the user's needs. However, we predefined the dimensions to avoid the content overflowing and becoming confusing to the user.



(a) First prototype (b) Full menu (5.1a) (c) Redesigned page

Figure 5.1. ACCESS+ Settings page before and after Redesign.

- **Icons labelling**. To support the understanding of standard icons (e.g., arrows, menu button, play button, etc.), we decided to add a textual label so that, even if the users do not recognize the icons, they have a textual alternative to understanding them. Nonetheless, the setting is optional so that users that can not read or find the addition of labels more confusing than helpful can hide the labels.

- **Different feedback options**. The user can give feedback by written comment, rating, or both.

- **Different rating scales**. The user can set the preferred rate scale. Either the Likert-scale Star Assessment (Fig. 5.3b) or the Emotional Assessment (Fig. 5.3a). We decided to emphasize negative, neutral, and positive emotions by coloring the icons red, yellow, and green since the differences between the three icons might not be recognizable by some users.

- **Textual content and AAC**. The application allows users to access content in textual form or its AAC representation (Fig. 5.2). AAC (mainly used by non-hearing and non-speaking users) allows people with intellectual disabilities to make sense of the text by looking at pictograms. Each word is carefully adapted and converted to a symbol. ACCESS+ leverages the Aragonese Center of Augmentative and Alternative Communication (ARASAAC) AAC API [16]. ARASAAC offers graphic and material resources adapted to facilitate communication and cognitive accessibility. Its API allows us to find the best AAC representation (pictograms) for each word/concept in the application content.

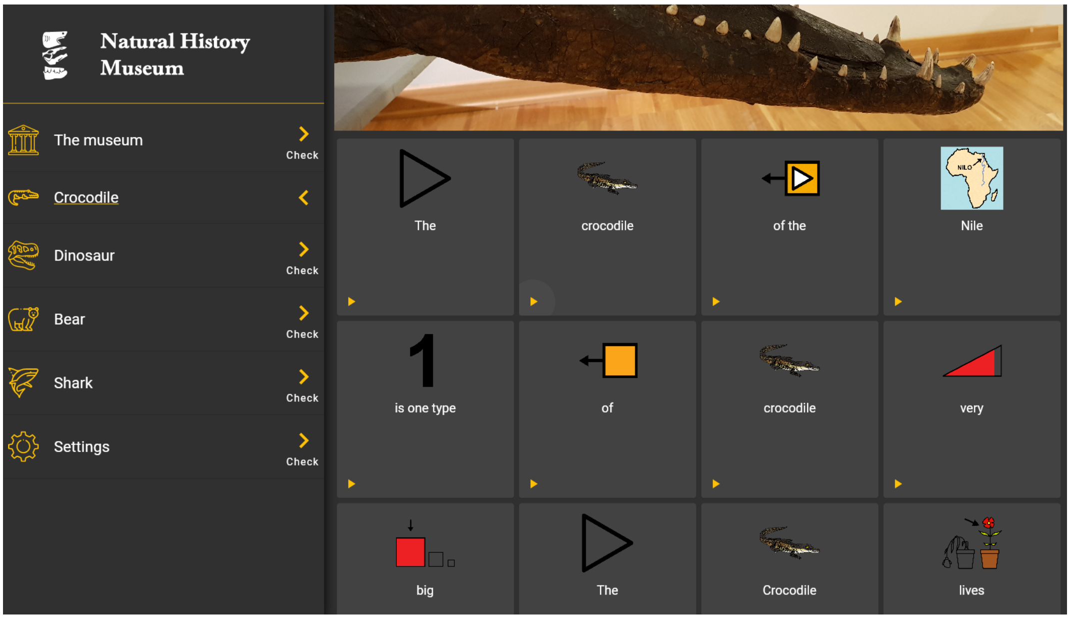
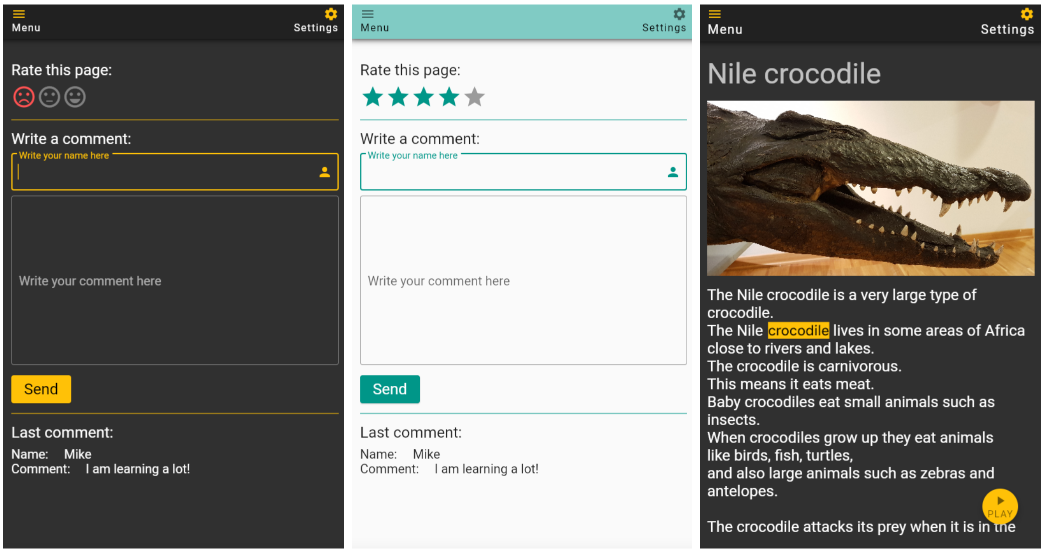


Figure 5.2. AAC feature with Dark Mode and Landscape tablet orientation.

- **Text-to-speech**. ACCESS+ also implements text-to-speech. This feature works differently depending on the selected content format (textual or AAC). When the content is textual, the user can listen to the text by pressing the Play button that switches to a Stop button during the reading. The user can also activate the highlight functionality that highlights the currently read word, and this should allow users to follow along more easily (Fig. 5.3c). When the content is in AAC, the user can press the Play button under each pictogram to activate the text-to-speech (Fig. 5.2). In both cases, it is possible to set the tonality of the voice and the playback speed (Fig. 5.1b).

5.3 Heuristic Evaluation and Redesign

We asked two special education experts to analyze the first prototype and give feedback about possible improvements. One of them is an educator, and the other



(a) Emotional Assessment (b) Likert-scale Assessment (c) Text-to-speech feature

Figure 5.3. ACCESS+ rating modes, comment section and text-to-speech feature highlighting text.

is a psychologist with long-term experience working with people with intellectual disabilities. Unfortunately, due to the COVID-19 pandemic, we could not proceed to an in-person co-design session and evaluation while designing and developing this app.

One of the experts noticed that the text in easy-to-read language had incorrect line wraps. The line's wraps play an essential role in pacing text and making it easy to understand. Regrettably, viewing on a small device such as a smartphone makes it difficult to structure the sentences precisely, and the experts have already had this problem on other occasions. We made some improvements on this aspect.

Another feedback was related to the evaluation and comment elements. Experts mentioned that it would be interesting to understand if the different rating formats and comment sections will be intuitive to grasp or disruptive.

The next consideration was relative to how intuitive the icons could be. The start and stop of the AAC icons seem intuitive from the experts' perspective, but it requires future investigation.

The experts described the settings page layout as problematic. We redesigned the page organization to be more straightforward. For example, the setting to change the icon size was hidden in the first prototype (Fig. 5.1a). This information not readily available would have forced users to take an extra step to be able to enlarge or reduce the icons' size independently from the font size. After the redesign, the setting is immediately available (Fig. 5.1c).

We redesigned and changed the terms used in the interface from being system-oriented to user-friendly. For example: instead of "Active AAC" we used just "AAC"; "Dark-mode" was changed to "Dark background"; we changed the "Return" button to "Back"; and "Icons with Labels" was modified to simply "Labels".

5.4 Co-designing ACCESS+

This section outlines the different steps of the co-design process to develop ACCESS+ after we could finally involve participants in our studies. We conducted three research visits (nine days in total) with 20 adults with intellectual disabilities to understand their needs and collect requirements, iterating the application as needed. The research team included technology experts, a psychologist, a museum professional, and two educators.

The successful execution of this study was facilitated by an enduring agreement between the participants' association, the involved research organization, and the formal approval obtained from the ethical committee of the researchers' institution. Before data collection, we ensured the informed consent of the participants and their guardians. Throughout the study, we gathered audio and video data for comprehensive analysis, taking utmost care to remove any sensitive information before securely storing it.

The authors employed various tools to analyze the collected data, including Spreadsheets, Documents, and a Miro board. By meticulously mapping the participants' actions, reactions, and voiced opinions concerning specific subtasks, we were able to extract meaningful insights. The results were then carefully coded and clustered to identify key patterns and themes that emerged from the data.

5.4.1 Procedure

We used a combination of activities to trigger co-design and gathered more participant feedback. This insight implicitly and explicitly enabled us to improve the app between visits (Fig. 5.4). We encountered unforeseen challenges during RV1 due to the prevailing COVID-19 restrictions, which necessitated improvisation techniques [277] to adapt and overcome the obstacles.

Our visits started with focus groups to get to know the participants and understand their prior knowledge about the animals we planned to introduce. The group discussed the content (animals of the Natural History Museum) through

Figure 5.4. Representation of the main steps for designing and evaluating ACCESS+.

written responses or drawings according to their abilities, and we reviewed the key details about each animal with an easy-to-read text.

Following each museum visit, participants engaged with the app, giving them a preview of the captivating encounters they had at the museum. In the first Research Visit (RV1), participants learned about dinosaurs, in the second (RV2) about crocodiles, and in the third (RV3) about wolves and reindeer. We also asked questions during the study to assess their technology habits and preferences. These activities were carefully planned in collaboration with stakeholders to ensure alignment with the visit's educational objectives and participants' interests.

During RV1, we evaluated the usability of an existing museum website and tablet application. This session aimed to determine what participants liked and disliked about the current solutions. We used a task-based approach to engage them and, ultimately, asked about their preferences. Tasks included finding the museum page, the dinosaur page, the museum address, the museum opening time, and a specific room on the museum map. The qualitative research focused on their preferences between devices, solutions, and UI elements.

RV2 and RV3 focused primarily on enhancing the ACCESS+ interaction. The participants engaged in a two-step process where they initially visited the museum and later utilized the application to retrieve information related to their visits. Through a task-based usability testing approach, participants could customize various aspects such as icon and text sizes, backgrounds, labels, and voices to cater to individual preferences and requirements. Users also made sense of the museum content by looking at symbols using AAC and listening to full-text TTS with personalized tone, pitch, and highlight settings. Some participants shared their thoughts, helping us to improve the accessibility of each choice and to add new features based on what was unclear or missing. Other participants provided non-verbal feedback that their educators interpreted.

5.4.2 Participants

A total of 20 participants, comprising 13 women and 7 men, with ages ranging from 21 to 63, took part in this study (refer to Table 5.1). All participants were from Italy. For each research visit, 12 participants were available. Participants P6, P7, P8, P16, and P20 were present in all research visits, although they may not have attended every specific session. P6, P7, and P8 participated in all the task-based usability testing sessions, while P6, P7, P8, P16, P15, P18, P19, P20, and P21 attended all the ACCESS+ co-design sessions (RV II and RV III).

Throughout the visits, we emphasized to the participants that they had the freedom to opt out at any time, and we reiterated the study's objectives. Some participants were absent from certain activities during a particular research visit or from an entire research visit due to illness, being new to the group, or other pre-existing commitments outside of the study. These factors were controlled by their respective institutions, and the researchers did not exert any influence on their individual freedoms. To ensure participant comfort, the activities were designed to be concise, and regular breaks were included. Additionally, the researchers arranged for sufficient time intervals between sessions with the assistance of educators who were familiar with the participants.

5.5 Findings

5.5.1 Usability of an existing museum website and application

Website

Most participants randomly touched the interface's elements to achieve their tasks, which suggested that the interface needed to be more explicit and intuitive for these users. The website was not designed with people with intellectual disabilities in mind, which could explain the cognitive overload. Additionally, some participants who needed help reading text had to rely on images and icons to navigate the website.

Table 5.1. Participants' demographic and research context information.

PID	Gender	Age	Research Visit	Presence	Context
P6	Woman	20-25	RV3 to RV5	In Person	Association and Museum
P7	Woman	40-45	RV3 to RV5	In Person	Association
P8	Man	30-35	RV3 to RV5	In Person	Association and Museum
P9	Man	60-65	RV3	In Person	Association
P10	Woman	30-35	RV3	Online	Association
P11	Woman	50-55	RV3 and RV5	Hybrid	Association
P12	Woman	50-55	RV3	Hybrid	Association
P13	Woman	20-25	RV3 and RV4	In Person	Association and Museum
P14	Woman	20-25	RV4	In Person	Association
P15	Woman	50-55	RV4 and RV5	In Person	Association and Museum
P16	Woman	60-65	RV3 to RV5	In Person	Association and Museum
P17	Man	25-30	RV3	In Person	Association
P18	Woman	45-50	RV4 and RV5	In Person	Association and Museum
P19	Man	50-55	RV4 and RV5	In Person	Association and Museum
P20	Man	45-50	RV3 to RV5	In Person	Association and Museum
P21	Man	55-60	RV4 and RV5	In Person	Association and Museum
P22	Woman	45-50	RV3	In Person	Association
P23	Man	20-25	RV4	In Person	Association
P24	Woman	50-55	RV5	In Person	Association and Museum
P25	Woman	55-60	RV5	In Person	Association and Museum

The study also found that the return button on the interface was difficult to find for all participants, regardless of their experience with technology. The arrow icon used for the return button was not intuitive enough for novice users, as they required verbal or gestural prompts to navigate back to the previous page successfully. This presents a semiotics engineering challenge, as modifying the icon, training participants, or adding more information may be necessary to make it more intuitive for users with different experience levels.

Despite the difficulties with navigation, the study found that certain website elements were easy for participants to find. Specifically, the address and opening hours of the museum were easy to locate, as they were familiar to the participants. Additionally, some participants associated tasks with previous experiences. For example, P12 mentioned that she had been to the museum in the morning when asked about the opening hours.

App

The lack of labels or any other descriptive information made it challenging for participants to understand the meaning of the icons on the landing page (Fig. 5.5). This finding highlights the importance of providing clear labels and additional relevant information to support people with intellectual disabilities in navigating digital interfaces.

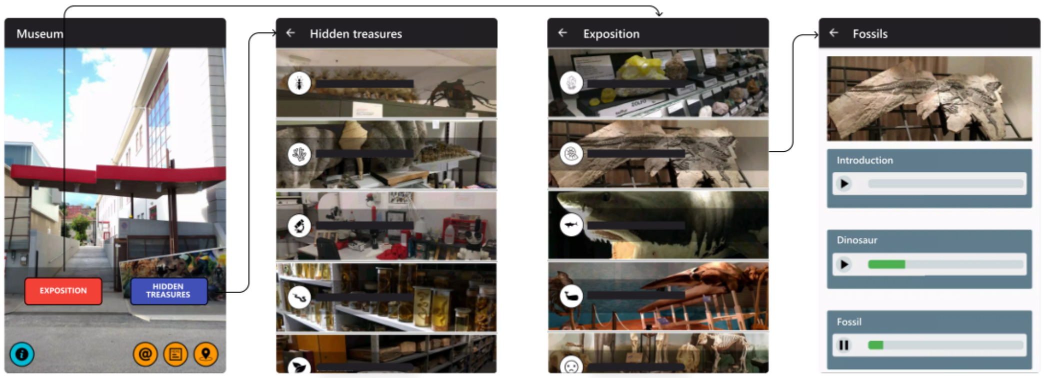


Figure 5.5. Screens of the Museum application, which was tested on the first research visit.

On the other hand, participants quickly accessed the exposition area section and the fossils page thanks to icons and a background image that helped illiterate participants, highlighting the potential benefit of visual aids in supporting people with intellectual disabilities in navigating digital interfaces.

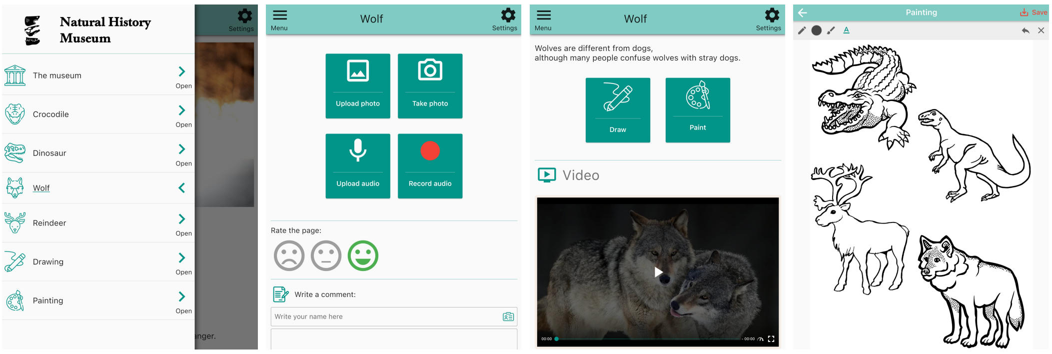
Another problem arose with Android's soft keys. Aside from the soft key of the back button present in the Android navigation bar, there was also the back button in the top bar of the application. This ambiguity made navigation confusing for participants, who accidentally tapped the soft key instead of the app back button, causing them to exit the app. These findings underscore the significance of consistency and simplicity in UI design, especially for individuals with intellectual disabilities who may struggle with complex visual information. Nevertheless, despite the quantity of content on the interface and the availability of icons and pictures, the app did not cause cognitive overload.

5.5.2 ACCESS+ app

The design of ACCESS+ incorporated researchers' experience, literature, heuristic evaluation, and feedback from RV1. We included icons, labels, AAC pictograms, and TTS to help users understanding. This first version also considered customizable icon sizes, a dark background, and different input modalities for commenting and rating. We used Flutter, an open-source UI development kit, to create a responsive cross-platform application.

We started RV2 and RV3 with exploratory testing on the ACCESS+ app in landscape mode on an iPad, allowing participants to become familiar with the touchscreen interaction modality. At this stage, we noticed challenges related to responsiveness and repetition. P16 was interacting with the app without scrolling unless prompted, which influenced the content she saw, affecting her effective search for information and, ultimately, her overall experience. In contrast, P20 was scrolling after a quick gesture prompt, demonstrating a solid understanding of the touchscreen interaction modality. In this exploratory phase, we asked participants to verbalize what they saw. Some participants answered in detail, while others needed verbal scaffolding to start this conversation.

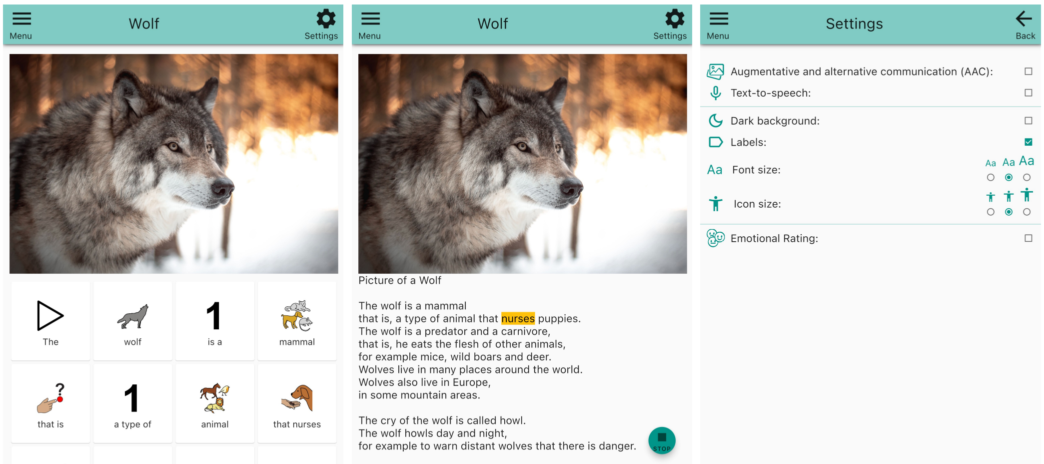
The task-based usability testing began by searching "The museum" on the menu (Fig. 5.6a). We designed a menu with icons, text, arrows, and labels based on 5.5.1 findings. The majority could find it quickly because they could read or understand the icon. P21 required assistance in both RVs to locate the option. P21's low vision and difficulty with reading may have contributed to the challenge of identifying the correct choice.



(a) Menu (b) Photo, audio, and input (c) Creation and video playback (d) Painting feature

Figure 5.6. ACCESS+ menu, blocks, input, and video: features to spark participation and engagement.

The next task on RV2 and RV3 was to locate a specific animal on the menu. Upon accessing the right page, a picture and the first few lines of content were displayed (Fig 5.7b), requiring participants to scroll down to read further. While most participants could scroll independently, some needed verbal or gestural prompts as a form of scaffolding. During the task, we observed P8 experiencing distractions and frustrations, requiring a supportive mood to participate fully.



(a) AAC text (b) Easy-to-read text with text-to-speech (c) Settings

Figure 5.7. ACCESS+ app with different features.

One issue we identified was that some participants needed a gestural or verbal prompt to find the app settings, indicating a need for familiarity with that icon. To address this, we adapted the version used on RV3 to provide a linkable area on the labels and nearby regions whenever possible. We also tested the understanding of the naming and icons available in each feature, and the last version is available in Fig. 5.7c. However, there are still icons without a design standard, such as AAC, which makes it hard to represent them efficiently.

We also proposed a dark background feature to improve readability and reduce eye strain. However, this divided opinions among participants, and some changed their preferences when we compared both RVs' answers. Due to their needs, we also increased the font and icon size on RV3. Another issue we identified that needed clarification was the fixed menu in landscape mode on RV2. Participants were looking for information on only one part of the screen, so we decided to hide it automatically after it appeared and the participants selected a page to navigate.

We tested easy-to-read text with TTS with word highlighting (Fig. 5.7b). P6 successfully used the TTS feature after receiving verbal instructions, but P19 experienced difficulty adjusting the voice speed. While some participants found the TTS feature helpful, others needed clarification or couldn't focus while reading and listening to the text.

P17 is a non-verbal participant that uses AAC to communicate. He communicated through his AAC notebook or provided gestures. His contribution was essential since he could tell us which were complex pictograms (Fig. 5.7a) as a daily user. He was happy to touch the interface and listen to each pictogram at a time with TTS. P15 said it was "*Very easy! I pressed an image, and the iPad spoke*".

The majority of participants preferred emotional rating scales as a way to provide feedback. However, P25 said, "*I prefer stars since the smileys were a little sad*". In response, we increased the size of icons and selected three emotional expressions with colors (red to sad, yellow to neutral, and green to happy). Additionally, we incorporated a 5-star Likert scale, although most participants found it challenging to understand this rating system. Participants liked to write comments, but illiterate participants would require an AAC keyboard or speech-to-text.

In the RV3 museum activity, we individually asked participants to freely choose which solution they would like to use to learn more about the museum content. They had five alternatives, three high-tech (ACCESS+, Augmented Reality, and a Multisensory Diorama) and two low-tech (printed easy-to-read text and AAC). ACCESS+ was the first preference of 4 participants, the second preference of another 4, the third preference of 2 participants, and the fourth and fifth of one.

We added extra features based on the feedback we collected from RV2 and RV3. The buttons became bigger blocks to help participants find and interact with them. Fig. 5.6b shows an example of a block and introduces new features: taking and uploading photos and recording and uploading audio. These features were important to participants who visited museums and wanted to remember information in different media formats. The blocks provide a visible link, including familiar icons to our participants. Fig. 5.6c shows the Drawing and Painting features. When clicking on the painting block, users will be redirected to its page (Fig. 5.6d) with a black-and-white image of the content ready to be painted.

5.6 Discussion, Reflections, Limitations & Future Considerations

It is essential to recognize that a museum app must serve as a support to the conventional, human-led learning experience that people with intellectual disabilities are accustomed to in an educational environment. As P9 mentioned, "First, I prefer to learn alone, after with an educator. I feel more prepared if I read myself to explain to the educators."

This chapter primarily emphasizes the iterative design process of ACCESS+

and its development in close collaboration with individuals with intellectual disabilities. Ensuring the UI is intuitive and simple is paramount, as people with intellectual disabilities may need help with complex navigation. Also, listening to users independently of their abilities is essential to design an accessible solution. Here are a few reflections on issues to consider when co-designing accessible applications with people with intellectual disabilities:

- **Education:** Providing education and training sessions is crucial when conducting co-design and usability testing with participants with intellectual disabilities [108, 132]. Workshops can be designed to help participants understand how to use the technology involved in the testing process, such as touch screens or computer mice. This will increase their confidence and ability to engage effectively with the testing process.

- **Support:** The role of the educator or support worker is essential in conducting co-design and usability testing with participants with intellectual disabilities. Educators can provide guidance and support during the testing process [226], helping participants navigate the application and complete tasks successfully. Additionally, participants can help one another directly or indirectly by providing feedback that can be applied to other participants.

- **Emotions:** Participants with intellectual disabilities may enjoy using technology but only sometimes know how to use devices effectively. It is important to consider their feelings when conducting co-design and usability testing. Participants may feel frustrated or embarrassed if they cannot complete a task, so creating a supportive environment that encourages them to ask for help and provides positive feedback is essential [132].

- **Complexity:** The co-design and usability testing process should be designed to be as simple as possible [87]. Participants with intellectual disabilities may lose attention if the tasks are too complicated or the application is too challenging to navigate. Using simple language, clear instructions, and avoiding cluttered or confusing interfaces is important. Keeping the testing process straightforward and clear will help participants engage with the testing process.

- **Attention:** Participants with intellectual disabilities may struggle with concentration and focus due to the co-morbidity of intellectual disability and attention deficit hyperactivity disorder (ADHD) [11], so it is crucial to design the co-design and usability testing process with this in mind. For example, tasks should be broken down into smaller, more manageable steps. The application should be designed to minimize distractions and encourage participants to stay engaged.

- **Readability:** It is crucial to consider the readability of text used in the co-design activities, as participants with intellectual disabilities may need help with abstract or complex concepts [89].

- **Navigation:** The risk of getting lost is high, especially when navigating on very crowded pages. Interactive maps and navigational aids should be co-designed with participants as the best way to keep the focus on their needs.

One notable limitation of this study stems from the participants' particular affinity for the museum content, which may account for the overwhelmingly positive feedback and their enthusiastic anticipation of visiting the museum. It is plausible that different groups engaged in co-designing a museum application may not exhibit the same level of enthusiasm. Additionally, this study is confined to a single-site investigation focused on a natural science museum, thereby limiting the generalizability of the findings. However, ACCESS+ was adapted and used in Australian workshops, broadening its impact. Furthermore, language and demographic representation were restricted here, as the study presented here was conducted exclusively in one language and within a single country.

The importance of recognizing that each participant has diverse and specific needs cannot be overstated, and as such, we must acknowledge that our solution may not be universally effective. Despite this, our approach is designed to cater to a broad spectrum of needs, including needs from those with and without disabilities, making it a significant addition to accessibility research. By acknowledging and addressing these limitations, we aim to improve accessibility in museums and contribute meaningfully to the expansion of knowledge in this field.

5.7 Conclusions

This chapter outlined the development and evaluation of ACCESS+, an accessible application co-designed with individuals with intellectual disabilities to improve museum accessibility. It emphasized the crucial role of communication and how technology can facilitate access to cultural heritage content. The chapter also describes the collaborative design process involving experts, individuals with intellectual disabilities, and partnerships with educational institutions and museums. The heuristic evaluation and redesign phase involved feedback from special education experts, leading to improvements in text readability, icon intuitiveness, and settings page layout. The application underwent multiple rounds of testing with stakeholders and individuals with intellectual disabilities, focusing on usability and the effectiveness of its features. Challenges included ensuring intuitive navigation, the need for additional training for participants, and the importance of inclusive design principles.

This study kept on the groundwork for exploring RQ 1.2 and addressed RQ 2.2: "How does the use of accessible applications influence the access to and engagement with museum content for individuals with intellectual disabilities?". The response is summarized in several main points:

- **Enhanced Accessibility**: Customizable features in the ACCESS+ application, such as adjustable icon and text sizes, high contrast modes (light and dark modes), and the inclusion of AAC pictograms, make content more accessible. These features cater to the varied needs of individuals with intellectual disabilities, enabling them to better understand and engage with museum exhibits.

- **Improved Engagement**: The application's design, which incorporates easy-to-read text formats, text-to-speech functionalities, and emotional rating scales, supports users' engagement by allowing them to interact with content in ways that match their preferences and abilities, fostering a deeper connection with museum content.

- **Broader UX Considerations**: The study highlights the importance of considering a wide range of UX factors, such as the intuitiveness of the UI, the simplicity of navigation, and the supply of clear instructions. These factors are crucial for creating applications that are truly accessible and enjoyable for individuals with intellectual disabilities.

- **Positive Feedback and Preferences**: The feedback from participants who interacted with the ACCESS+ application was positive, indicating a preference for using such accessible applications to engage with museum content. Even if this feedback should be interpreted case by case, the application successfully addressed some of the barriers that individuals face in traditional museum settings.

Finally, the application's features can benefit a bigger amount of users, including those with limited or emerging reading skills, such as the illiterate and children. Further investigation will require additional involvement of participants and co-design sessions to improve the UI design. We learned a lot during this process, mostly about how to fruitfully collaborate with people with intellectual disabilities. Still, we were once again reminded how technology used in museums is far from being widely accessible. The following chapter, Social Robots, will continue the exploration of Digital and Interactive Technologies by analyzing the usage of social robots as co-facilitators in museums and to provide entertainment.

6

Social Robots

The exploration of social robots has emerged as one of the leading innovations in the rapidly evolving field of HCI, thanks to their growing capabilities and increasing presence in a wide range of sectors, including education, healthcare, and cultural settings. The novelty of social robots lies in their advanced interactive technologies and marks a significant leap from traditional robotics, fostering social connections and enhancing human experiences. Our focus on social robots in the context of museum-guided tours, alongside researchers and an engagement officer, stems from a desire to investigate the dynamics of human-robot interaction in enriching cultural experiences. This study focuses on the role of a semi-humanoid robot, which has a tablet attached, in co-facilitating museum tours. By doing so, we investigate the potential of social robots to engage visitors with intellectual disabilities.

This work, completed in Australia during my doctoral mobility studies, is the conclusion of my doctoral dissertation's Part II efforts. It is one of the chapters that provide content to answer RQ 1.2 (*How can we involve people with intellectual disabilities in the evaluation of digital and interactive prototypes for museum visits?*) and to address RQ 2.3 (*How does the use of social robots influence the access to and engagement with museum content for individuals with intellectual disabilities?*). This work makes numerous contributions to human-computer interaction: it provides empirical insights into the effectiveness of social robots in engaging diverse audiences within museum environments; it advances the understanding of design considerations and challenges in developing social robots for public settings; it contributes to the discourse on the ethical implications of deploying social robots in educational and cultural contexts.

6.1 Introduction

Museums are invaluable cultural institutions that serve as gateways to knowledge, art, history, and culture, offering a wealth of educational and enriching experiences. These vibrant hubs of learning and inspiration provide visitors with opportunities to explore the past, appreciate artistic masterpieces, and connect with the world's diverse heritage. However, for individuals with intellectual disabilities, museums often present significant accessibility challenges due to complex exhibits and sensory stimuli [228]. This can be overwhelming and intimidating, limiting their ability to fully engage with and benefit from these enriching environments.

This study investigates the potential of social robots to enhance the engagement and participation of individuals with intellectual disabilities in museum settings. Social robots have emerged as a transformative technology, capable of sustaining engagement [26], fostering social interactions, providing personalized assistance, and adapting to diverse user needs [255]. By integrating social robots into the museum environment, we aim to create more inclusive experiences for individuals with intellectual disabilities.

Our investigation explores design considerations, challenges, and potential benefits associated with the incorporation of social robots as assistive tools in museums. We also consider their role in engaging people with intellectual disabilities through interactions before and after their museum visit. Through the analysis of emerging trends in the observations of 6 participants over a 3-week engagement, we seek to provide empirical evidence of the impact of social robots on the overall experience of individuals with intellectual disabilities in these different settings.

Preliminary findings from our research suggest that social robots have the potential to enhance the accessibility of art knowledge, foster social interactions, and increase overall satisfaction with museum experiences among individuals with intellectual disabilities. However, the successful integration of social robots into museums will necessitate careful consideration of various factors, including technological limitations, design consideration, implementation, ethical concerns, and the unique requirements of the target audience.

This chapter is organized as follows: In Section 6.2 we describe our study settings, including a description of our participants, the procedure, and ethical considerations. Section 6.3 presents trends from our observations of three workshop sessions. In Section 6.4 we discuss their implications for designing inclusive museum experiences, shedding light on the promising future directions for research and development in this domain. A comprehensive exploration of the intersection between technology, accessibility, and culture was already introduced in Section 2.7.

6.2 Methodology

6.2.1 Participants

The study involved participants with intellectual disabilities who visited a museum and interacted with a semi-humanoid social robot called Pepper, manufactured by Softbank Robotics[1]. The participants were recruited through local disability support organizations that only support adults with a diagnosis of intellectual disability and were selected based on their interest and willingness to participate in the study. The sample consisted of 6 individuals (M/W: 5/1). We organized the participants into two groups for the museum visit. Group 1, with P27 to P29 (age range: 40s, 40s, and 30s), and Group 2 with P30 and P32 (both in their 20s years old). P31 is in his 20s and joined the group on the third workshop. Participants were all supported in a 1:4 ratio to take part in community-based activities. Their verbal abilities ranged from using a few words only to clear verbal expression. They were all able to understand simple instructions. QUT's ethics committee approved the research. The protocol promotes voluntary and informed involvement by providing participants with easy read consent forms, verbal reminders while they participate in the study, and tracking body language for signs of a potential desire to abandon the study. 2 carers were also present during the study and signed consent forms, however, this chapter only focuses on target participants.

6.2.2 Research Team

Our research team consisted of two computer science PhD students and two computer science professors, who were responsible for writing the research paper resulting from the study, conducting the research, and/or implementing the project. In addition to this core team, during the sessions, we had assistance from three psychology students who were tasked with making observational notes, a supporting researcher with expertise in the disability sector who provided general assistance, advice, and reflections, and one student who was in charge of video recording the sessions.

[1]www.softbankrobotics.com

6.2.3 Procedure and Design

The study was conducted through three workshops, each focusing on different aspects of engaging people with intellectual disabilities through social robots in museums. The workshops occurred at the QUT Gardens Point campus and the QUT Museum in Brisbane, Australia.

First workshop - AW1 (P27, P28, P29, P30) The initial workshop aimed to familiarize the participants with the museum artworks and introduce them to the social robot Pepper. The workshop started with participants learning about the museum artworks using ACCESS+ – an accessible application designed with and for people with intellectual disabilities to navigate museum content – which provided accessible information about the exhibits. During this session, the first author facilitated the group, along with support from other researchers and psychology students. Then, participants had the opportunity to interact with the robot by watching dance performances, selecting actions, and playing games.

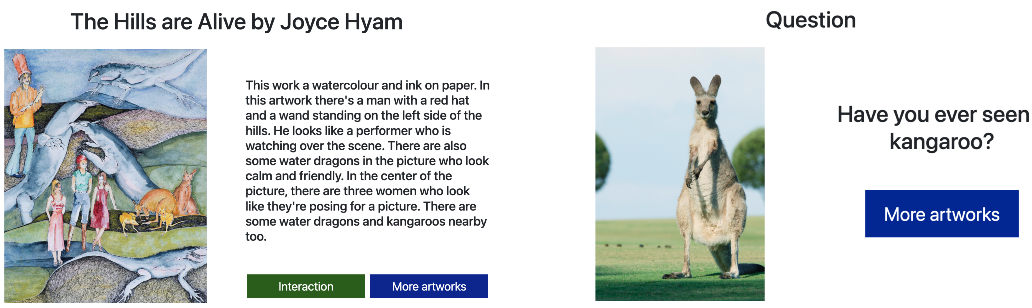
Second workshop - AW2 (P27, P28, P29, P30, P32) The second workshop focused on the museum visit and the role of Pepper as a cultural mediator. The participants were divided into two groups. Group 1 visited the museum, where Pepper, acting as a co-facilitator alongside a museum engagement officer, presented information about the artworks. The museum engagement officer provided additional insights, enhancing Pepper's explanations. A picture of Pepper in the museum with the artworks is available in Fig. 6.1b.

(a) Participants drawing. (b) Pepper in the museum.

Figure 6.1. Activities during the second workshop: Participants drawing and Pepper in the museum.

Meanwhile, Group 2 remained in a designated room. They revisited their knowledge of the artwork with the museum application and were invited to use as well pen and paper to explore their understanding and reflections on the artwork and the social robot's role. Fig. 6.1a shows a picture of this moment. The participants' drawings represented what they liked the most about their visit. Later, we swapped the groups and Group 2 went to the museum while Group 1 came back to the research room. We had two researchers who facilitated the museum activities, while the other two facilitated the activities in the research room. A researcher video-recorded the activities in each setting.

In this study, the robot Pepper was configured to exhibit three distinct artworks. Each artwork was presented on a dedicated page on the tablet, as exemplified in Fig. 6.2a. The layout of these pages was meticulously designed, featuring the artwork prominently on the left side, its title at the top, and a detailed textual description adjacent to the artwork. Additionally, two interactive links, labeled "Interaction" and "More artworks," were placed at the bottom left of the page. As shown in Fig. 6.2, selecting "Interaction" initiated a transition to a new page. This page, depicted in Fig. 6.2b, was composed with an image symbolizing the core subject of the question on the left, the word "Question" at the top, and the question itself positioned on the right, accompanied by a link redirecting to "More artworks". In the given example, the question posed was, "Have you ever seen a kangaroo?", paired with an illustrative image of a kangaroo. Pepper was programmed to delay its response by one minute. This pause allowed the researchers and the engagement officer to simulate the Wizard of Oz technique, fostering an interactive discussion before Pepper's contribution. In this specific instance, Pepper responded with, "That's great! I've never seen a kangaroo before. Can I find one around here?" This approach effectively created an engaging and interactive experience, granting participants the feeling of genuine participation from the robot.



(a) Description of the artwork. (b) Question read by Pepper.

Figure 6.2. Pepper's interactive application used during the museum visit.

Third workshop - AW1 (P27, P28, P29, P30, P31) The third workshop began with participants drawing and expressing their favorite aspects of the museum visit and also using the ACCESS+ app on a tablet if they wanted to. Then, participants used Pepper to play a quiz game focusing on the museum artworks. The quiz consisted of choosing between two alternatives, with only one of the artworks available in the museum. The participants were guided to access information about the museum artworks they had previously encountered. The first author facilitated the workshop and provided support throughout the creative process [115]. During the workshops, participants could contribute with extra drawings.

6.2.4 Data Collection and Analysis

Data was collected through various methods throughout the workshops, including observations (as notes taken during and after the workshop), audio recordings, and video. The observations captured the participants' interactions with Pepper, engagement levels, and reactions to the robot-mediated experiences. Audio recordings were used to transcribe and analyze the conversations and utterances during the workshop activities. The video recorded participants during all the workshop sessions, focusing on the human-robot interaction and the museum experiences. At the end of each workshop, once the participants had left, we also recorded a debriefing session where the researchers and psychology students discussed the workshop outcomes.

The collected data was analyzed using qualitative methods, including thematic analysis [67] of the observations, audio, and videos that were coded into relevant topics by the 2 first authors of the research paper [115]. The results of the data analysis were then used with the rest of the authors to identify patterns, themes, and insights related to the engagement and participation of individuals with intellectual disabilities in museum environments through the use of social robots.

6.3 Findings

6.3.1 AW1: Introduction to Technology and Initial Reactions

The first workshop was characterized by a mix of low and high engagement among participants. Initial engagement was predominantly low, with some participants being distracted, for instance, by the sound of the room's door. However, based on our observations and the analysis of verbal and non-verbal responses, the engagement levels increased significantly with the introduction of the ACCESS+ app and the robot Pepper.

Consistent with previous findings [246, 275], the ACCESS+ app was effective in capturing and maintaining the attention of participants during the introduction of the museum and its artworks. This engagement was notably enhanced compared to the reception phase where technology was not employed. We observed from both explicit comments, facial expressions, length of use, and overall body language that the app's functionalities, which included drawing, painting, and reading or listening to content, were well-received. These clues point to a high level of engagement indicating comfort and interest in technology, especially in the context of learning and creative expression.

Following the use of the ACCESS+ app, Pepper was introduced to the participants and they saw Pepper performing activities such as dancing or a game with comical trick questions (jokes). The reactions towards Pepper varied. Most participants, less familiar with advanced technology, exhibited greater appreciation for Pepper, with smiles, and actively engaging with the content. This contrasted with P30, a tech enthusiast participant who verbally reported higher expectations, influenced by portrayals of robots in popular games and TV shows.

The participants demonstrated a wide range of behaviors and responses to the introduced technologies. Participants' reactions ranged, from shy to outspoken, emphasizing the need for a broad range of technological strategies. Nonetheless, the use of familiar technologies, such as tablets and smartphones, significantly increased engagement, particularly among those who initially appeared passive or distracted (P27, P28). While most participants expressed their interest through actions and body language, P30 exhibited a critical and analytical approach, providing valuable verbal feedback on the technologies used. His engagement with the app, especially after exploring features like text-to-speech, and his feedback on its utility for individuals with intellectual disabilities, underscored the importance of considering diverse user needs in technology design and the different roles participants can play.

6.3.2 AW2: Museum Visit and Interaction with the Social Robot

Individual Behavioral Patterns

P27 showed fluctuating interest, was particularly attracted to creative tasks, and expressed a desire to meet Pepper again. P28's engagement evolved from mixed to more focused and positive, especially during direct interactions with Pepper and artworks. P29 was consistently active, engaging in interactive tasks with enthusiasm. P30 stood out with a critical and analytical approach, especially in discussions about Pepper and its role as a co-facilitator, stating that Pepper could be "a good assistant for individual visitors", referring to his peers. In contrast, P32 exhibited limited engagement, often focused on his personal technology devices (mobile phone and headphones), indicating a need for different strategies or activities.

Emotional Response

The emotional responses of participants highlighted the diverse impacts of the workshop. P27 and P28 both showed moments of happiness, especially in response to interaction with Pepper. P29 maintained a predominantly happy and engaged demeanor, positively responding to both technology and art. P30's neutral emotional state was accompanied by a thoughtful approach, while P32's generally neutral or unhappy demeanor throughout both the first and the second workshop, despite active engagement in the app and drawing activities, suggested potential discomfort with both the group discussions and social aspects of the workshop in addition to a disinterest in the robot.

Interaction with Technology and Art

The implementation of the Wizard of Oz technique, involving deliberate pauses in Pepper's responses, fostered group discussions and interactive learning. Human facilitators also played a crucial role in complementing Pepper's functionality, especially in situations where the robot lacked full autonomy or specific capabilities. These facilitators worked alongside Pepper, providing additional information and facilitating the discussion among participants in the time between Pepper's questions and its reactions. P27 and P28 engaged positively with Pepper and showed interest in art-related activities. P29's engagement with tablet activities and artwork exploration was enthusiastic. P30, while skeptical of Pepper's capabilities, engaged in objective discussions about technology in art. P32's focus on their personal technology over workshop activities during the museum content and visit, highlighted the challenge of engaging certain participants with external stimuli.

6.3.3 AW3: Quiz Game and Artwork

The workshop started with participants drawing on paper and using the ACCESS+ app if they wanted – They could also draw on the app. This creative activity served as an ice-breaker and allowed participants to reflect on their experiences. The quiz game with Pepper, the social robot, was a key activity in this session. Each participant interacted with Pepper, demonstrating varying levels of engagement, understanding, and interaction with the technology.

Active Engagement and Support Needs: P27 demonstrated an active engagement with Pepper, starting the quiz game independently and vocalizing recognition of the robot. While he showed varying levels of success in answering questions, the need for and receipt of facilitator support (from support workers or researchers), especially for recalling artwork details, was crucial in enhancing his engagement and activity success. Similarly, P28, who volunteered for the activity, relied on facilitator scaffolding to begin. His interaction with the printed artwork and correct responses indicated positive engagement with the game. The support worker's acknowledgment of P28's successful game completion further reinforced the supportive environment of the workshop.

Focused Participation and Critical Perspectives: P29's interaction with Pepper stood out due to her high level of focus. She began the game immediately, without waiting for prompts, and successfully answered all questions, demonstrating a comfortable and engaged experience with the robot. On the other hand, P30 engaged promptly with the game after removing his headphones. His experience was mixed, showing frustration at Pepper's celebration animation but also completing the activity. P30's subsequent reflection on Pepper's suitability for children and colleagues showcased his critical thinking about the robot's broader applicability.

Inclusivity and Non-verbal Communication: P31, a new participant in the robot activity, displayed a fascination with Pepper. His ability to communicate with primarily non-verbal interaction, including gestures, nodding, and facial expressions, highlighted the activity's inclusivity and engagement despite familiarity with the artwork.

6.4 Discussion

6.4.1 Engagement with Technology and its Implications

The workshops revealed varied levels of participant engagement with technology, ranging from low to highly active. The introduction of the ACCESS+ app and Pepper served as pivotal points in enhancing engagement. Participants like P27 and P28 showed an evolving interaction with these technologies, shifting from initial passivity to active engagement, particularly in creative tasks and direct interactions with Pepper.

This shift in engagement levels underscores the importance of integrating familiar and interactive technologies in educational and recreational settings for individuals with diverse needs. The positive response to the ACCESS+ app and Pepper suggests that interactive technologies can be effective tools in increasing engagement and participation.

6.4.2 Diversity through Personalized Technology Integration

The diverse responses to technologies, from the ACCESS+ app to Pepper, highlight the need for flexible and personalized approaches in the design of technology-integrated workshops. Participants displayed a range of behaviors, with some like P29 showing high focus and enthusiasm, while others like P32 were more inclined towards the use of personal technology, indicating a preference for solitary activities. This diversity necessitates the adoption of a customizable approach in technology-integrated workshops. Tailoring activities to individual preferences and abilities can enhance overall participation and satisfaction, as evidenced by the varied engagement levels observed.

In museum settings, Pepper significantly enhanced visitor experiences through personalized interaction using speech and gestures. This method enabled engagement with the robot and encouraged interaction among participants, establishing a collaborative environment. It was successful as part of a collaborative approach with human facilitators, which created a dynamic and adaptive environment, effectively catering to the diverse needs of participants and mitigating the robot's limitations.

The workshops demonstrated the importance of inclusivity in technology-integrated activities. P31's non-verbal communication and fascination with Pepper underscored the inclusivity of the quiz game with Pepper. Additionally, the experience of P32, who showed a preference for personal technology devices, illustrates the need for diverse technological strategies to cater to different engagement styles. Activities that accommodate various communication styles and abilities ensure that all participants, whether they prefer interactive technologies like social robots or personal devices, can engage meaningfully.

6.4.3 Critical Feedback and Realistic Expectations

Participants with a strong technological background, such as P30, exhibited higher expectations and provided critical feedback. This aspect is crucial in understanding user expectations and improving technology integration in similar settings.

P30's critical perspective, particularly his reflections on Pepper's suitability for different audiences, provides valuable insights for future technological implementations.

Moreover, managing expectations, especially for participants familiar with advanced technology or gaming, is essential. Realistic portrayals of what technology can offer and its limitations are key to aligning participant expectations with actual experiences. This is in line with the literature that identifies discrepancies between user expectations and experience [175]. For instance, users often anticipate more advanced abilities from technology, leading to a mismatch between expectations and reality. This gap is particularly pronounced among users familiar with advanced technology through fiction or gaming, as they might have higher expectations of system performance.

The design of social robots significantly shapes user expectations in museum settings. Anthropomorphic features often lead users to expect advanced communication and emotional intelligence, an expectation rooted in Mori's "Uncanny Valley" [201] theory. Still, if the robot's functionalities don't align with its design, visitors may feel let down. Museums need to carefully balance the robot's appearance with its actual capabilities to avoid such discrepancies. Additionally, adapting the robot for accessibility, like adjustable heights, easy read, and text-to-speech features, ensures a better experience for people with intellectual disabilities.

6.5 Conclusions

This chapter highlighted the potential of technology, particularly social robots, in enhancing engagement and participation in informal learning in museum-related settings. Adaptable, personalized, and inclusive approaches are key to maximizing the benefits of technology integration. These insights contribute to the broader understanding of how technology can be leveraged to enrich experiences for individuals with diverse needs and preferences and underscore the need for more research in such informal learning contexts.

This study concluded the groundwork for exploring RQ 1.2, which will be discussed in Chapter 10, and addressed RQ 2.3: "How does the use of social robots influence the access to and engagement with museum content for individuals with intellectual disabilities?". The response is summarized in several main points:

- **Enhanced Accessibility of Art Knowledge**: Social robots like Pepper, equipped with a tablet displaying interactive content, can make art more accessible to individuals with intellectual disabilities by engagingly presenting artwork information through different modes such as voice, text, and gestures, facilitating understanding and appreciation of museum exhibits.

- **Increased Engagement**: The use of social robots significantly increased the engagement levels of people with intellectual disabilities by providing activities such as quizzes and interactive artwork information via the robot's tablet. The activities encouraged active participation and sustained interest in the museum content.

- **Fostered Social Interactions**: The social robots also played an important role in fostering social interactions among participants. The shared experiences of interacting with the robots, participating in the guided tours, and engaging in conversations started by the robot's prompt promoted discussions and exchanges between visitors, enhancing the overall museum experience.

Future research should focus on integrating a mix of familiar and innovative technologies while considering the diverse needs and preferences of participants. Researchers could engage more deeply with the context of the research, exploring the relationship between participant backgrounds, engagement levels, and technology expectations. Additionally, investigating long-term engagement patterns and the impact of repeated interactions with social robots would provide valuable insights for designing inclusive and effective educational and recreational experiences. This chapter finishes Part II of this doctoral dissertation, which explored different technologies and contexts. The following chapter, Multisensory Experiences will start the exploration of Creativity and Multisensory Integration by designing a multisensory experience diorama, allowing participants to interact with the content using multiple senses and modes of communication.

Part III

Creativity and Multisensory Integration

7

Multisensory Experiences

This chapter opens the Part III of my doctoral dissertation. It is one of the chapters that provide content to answer RQ 1.3 (*How can we use technology to involve people with intellectual disabilities in creative and multisensory experiences?*) and to address RQ 3.1 (*How do people with intellectual disabilities perceive and engage with a multisensory diorama?*). The focus on multisensory experiences in this chapter of the doctoral dissertation stems from a recognition, based on previous studies, of the need to move beyond digital and interactive technologies that primarily engage users via screens. This shift towards incorporating haptic feedback and diverse forms of input without relying on screens is crucial for several reasons. It acknowledges the barriers faced by individuals with intellectual disabilities in accessing and engaging with museum content, which often requires navigating complex information and interfaces. By leveraging multisensory experiences, the research aims to create more inclusive and accessible environments that cater to a broader range of learning styles and abilities.

Multisensory experiences, as explored through the implementation of dioramas in the museum context, offer an immersive and engaging way to facilitate learning and enhance the museum visit for people with intellectual disabilities. This approach prioritizes user-centric design and accessibility. Further, the use of tangible interactive objects, such as the Multisensory Diorama (MSD), exemplifies how physical interaction with educational content can promote engagement, learning, and meaningful experiences for participants.

This work contributes to the HCI field by demonstrating the potential of multisensory experiences to improve accessibility and engagement in informal learning settings. It emphasizes the importance of designing interactive technologies that support diverse sensory inputs and outputs, making content more approachable and enjoyable for individuals with intellectual disabilities. Through this research, we offer a promising direction for future innovations in HCI.

7.1 Introduction

Museums are spaces of knowledge and cultural heritage, offering a range of experiences that aim to inform, educate, and entertain visitors. Unfortunately, many people face barriers when accessing and enjoying museums, including people with intellectual disabilities. The barriers include the complexity of information and lack of inclusive interpretation. To address them, there has been growing interest in developing inclusive practices and accessible environments in museums. In particular, there has been a focus on enhancing the multisensory experience of museums by engaging multiple senses and modes of communication [139].

Multisensory experiences can facilitate learning and engagement and can enhance the accessibility of museums for people with intellectual disabilities. One approach to creating multisensory museum experiences is through dioramas, which are three-dimensional models or displays showing a scene or an event. Dioramas, which can provide a rich and immersive experience, allow visitors to explore different perspectives, time periods, and cultural contexts while promoting and enhancing learning and critical thinking.

This chapter explores the potential of multisensory experience dioramas to enhance accessibility and engagement in museums for individuals with intellectual disabilities. Specifically, Section 7.2 will present our objectives, implementation, and interaction and gamification plan. Section 7.3 will present the evaluation of a multisensory experience diorama designed for a museum exhibition. We will also discuss our findings in Section 7.4. We conclude this chapter and highlight limitations and future considerations in Section 7.5. Lastly, a review of relevant literature on intellectual disabilities, museum accessibility, and multisensory experiences was already introduced in Section 2.8.

7.2 Design

7.2.1 Rationale and objectives

Thanks to informal learning, museums can provide an effective informal alternative learning environment for people with intellectual disabilities. In particular, dioramas can provide explicit and immersive representations of information that can be more easily understood. After visiting a Natural History museum with people with intellectual disabilities and observing their reactions to playful interactions, we conducted a focus group session with a psychologist, educators, and the museum's researcher. Together we explored the feasibility, requirements, and features of a tangible interactive object to place inside the museum. Inspired by the literature and the museum's content, we envisioned a Multisensory Diorama (MSD) focused on the food chain. As the group of participants was going to learn content about wolves and reindeer, the educator suggested focusing on that topic and proposing an activity that could be placed inside their learning process. Following the focus group, the content of the museum, and accounting for the learning objectives of the participants, we extracted the key considerations that should have been taken into account during the design phase:

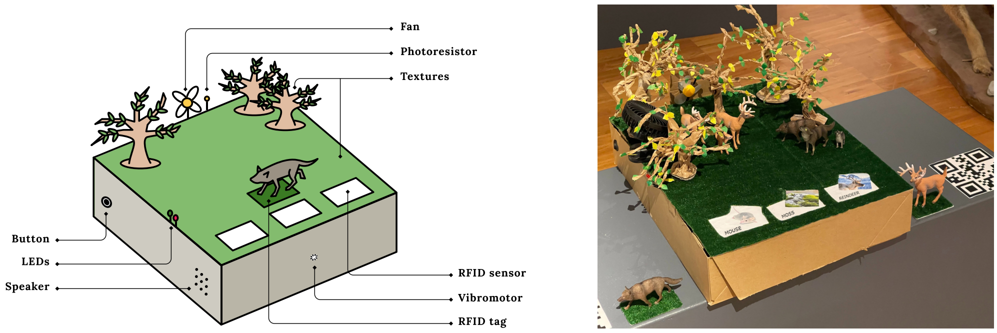
1. **Engagement:** The diorama should be designed to be interactive and engaging for the participants, to involve them in a memorable and meaningful learning experience;

2. **Accessibility:** The diorama should propose multisensory feedback to accommodate the specificities of the participant with intellectual disabilities. It should leave the participant the possibility to choose how to engage with it and should be easy to use;

3. **Learning:** The diorama should help contextualize and consolidate previous knowledge.

7.2.2 Implementation

The MSD presented in this chapter is a portable box with the scenery on top and the electronics inside. To recreate the landscape, a green textured cloth miming grass covers the surface. On the front are three cards with pictures and names of mouse, moss, and reindeer. Each card has its own RFID reader housed inside the box. Red and green LEDs are on the left side of the box and next to the cards. Statuettes of wolves and reindeer occupy the middle portion of the surface, and two of them stand on a white card-shaped RFID tag. Paper trees with thin branches and leaves that can easily shake with wind serve as a backdrop for the game. The wind is generated by a small fan located directly behind the trees. It can be activated by a photoresistor placed among the trees and a button on the diorama's left side. RFID readers, LEDs, the fan, the photoresistor, and the button are all connected to an Arduino Uno, which is equipped with an MP3 shield, a speaker, and an external battery. Fig. 7.1a shows the components.



(a) Components available on the MSD.

(b) MSD in the Museum.

Figure 7.1. MSD: Components' description and the box inside the museum.

7.2.3 Interaction and Gamification

The MSD offers visitors an interactive experience in a forest setting, where they can observe wolves and reindeer. The diorama is designed to provide two different ways of engagement and interaction, allowing visitors to choose their own experience and make their visit more memorable. Visitors can explore the augmented landscape, where they can touch the MSD's elements to discover their textures, activate the wind, and move the animals. This allows visitors to experience the forest environment hands-on and understand the different elements that make up the ecosystem. They can also play imaginative games set in the forest, which will make the experience more fun and creative.

In addition, visitors can play a matching game that reinforces their knowledge of the food chain in the forest. The game is based on the prompt "Who eats what?" and visitors can pick up the animals from the scenery and place them on top of the image of their food. The answers provided are mouse, moss, and reindeer. If the participant selects the wolf, the correct answers would be mouse and reindeer. However, if the participant selects the reindeer, moss is the correct answer. When the answer was wrong, a red LED lit up, and a feedback sound was played, encouraging participants to try again. On the other hand, if the answer was correct, a green LED lit up, and the speakers played a sound associated with the animal. Every time a match was made, the diorama vibrated. The game is designed to reinforce knowledge about the different animals and their role in the ecosystem in an interactive way. The simple mechanic and interaction are meant to enhance accessibility and improve understandability.

7.3 Evaluation

7.3.1 Method

To evaluate the accessibility and engagement of the MSD, we conducted a study at a Natural History museum during the fifth research visit (RV5). Participants were first given a tour of the museum room with the wolf and the reindeer and were given a brief refresher on the animals featured in the diorama. Afterward, the MSD (Fig. 7.1b) was placed on a table between the animal statuettes and a stool was provided for participants to sit on. The participants then entered the room individually for a one-on-one session with two researchers present. One researcher was leading the experience and was standing beside the participant to guide them through the activity, while the other researcher was standing in the corner of the room, taking notes on the participant's interactions and observations and filming the experiment for further analysis. Participants were first given the opportunity to explore the diorama freely. We then provided a brief overview of the MSD and its purpose, and later, the leading researcher presented the matching game promptly. The researcher handed the animal with the tag and asked the participant to place it on its food. At the end of the session with the MSD, the researcher showed participants any interaction that they hadn't tried at the beginning of the session. Finally, we requested that participants exercise their free will in selecting between the MSD and other familiar options, including a Museum app, an Augmented Reality app, printed easy-to-read text, and augmentative and alternative communication (AAC) pictograms. They were asked to choose their preferred option in sequence until the final alternative. After the session, participants were interviewed by an educator in a separate room, where they were asked to describe the diorama, the activity, and express their opinions about it. This approach allowed us to gather valuable feedback on the accessibility and engagement of the MSD and make any necessary adjustments for future implementations.

7.3.2 Participants

The study involved a sample of 12 adults with intellectual disabilities. 8 women and 4 men, who were chosen to participate in a museum visit by their educator from the same association. It was made possible by an ongoing agreement between the participants' association and the research organization involved and formal approval from the ethical committee of the researchers' institution. The association ensured that both legal guardians and participants knew the research purpose and that participation was voluntary. This was an important aspect of the study as it ensured that all participants were willing and able to participate in the experience. Three participants have mild intellectual disabilities (P16, P19, P20), eight have moderate intellectual disabilities (P6, P7, P8, P11, P15, P21, P24, P25), and one severe intellectual disability (P18), providing a representative sample of the population. Regarding age, 2 participants were under 40, 4 were between 40 and 50, and 6 were over 50. To ensure that all participants were comfortable during the study, frequent reminders were given that they could opt out of the activity at any time. This was an important step as it ensured that participants did not feel pressured to continue the activity if they were uncomfortable with it. For non-verbal or minimally verbal participants, their educators were present to ensure that their needs were understood and that they felt comfortable throughout the experience. The table below 7.1 provides a comprehensive overview of our participants, including their demographic information and diagnostic details provided by the association after obtaining their permission:

Table 7.1. Participants' demographic and diagnostic information.

PID	Gender	Age Range	Country	Attendance	Disabilities
P6	Woman	20-25	Italy	Museum (RV5)	Moderate Intellectual Disabilities
P7	Woman	40-45	Italy	Museum (RV5)	Moderate Intellectual Disabilities
P8	Man	30-35	Italy	Museum (RV5)	Moderate Intellectual Disabilities and Epilepsy
P11	Woman	50-55	Italy	Museum (RV5)	Moderate Intellectual Disabilities and Spastic Paraparesis
P15	Woman	50-55	Italy	Museum (RV5)	Moderate Intellectual Disabilities
P16	Woman	60-65	Italy	Museum (RV5)	Mild Intellectual Disabilities and Down Syndrome
P18	Woman	45-50	Italy	Museum (RV5)	Severe Intellectual Disabilities
P19	Man	50-55	Italy	Museum (RV5)	Mild Intellectual Disabilities
P20	Man	45-50	Italy	Museum (RV5)	Mild Intellectual Disabilities
P21	Man	55-60	Italy	Museum (RV5)	Moderate Intellectual Disabilities and Oligophrenia
P24	Woman	50-55	Italy	Museum (RV5)	Moderate Intellectual Disabilities and Down Syndrome
P25	Woman	55-60	Italy	Museum (RV5)	Moderate Intellectual Disabilities and Oligophrenia
P26	Woman	25-30	Italy	Museum (RV5)	Moderate Intellectual Disabilities, Non-verbal and Down Syndrome

7.4 Findings and Discussion

7.4.1 Initial observations

Participants were initially free to explore the diorama. We analyzed and clustered data based on similarities in behavior. Some participants (P6, P16, P18) focused more on physical interaction with the elements, such as touching and feeling, while (P7, P8, P20, P11, P15, P21, P19, P25) focused more on verbal expression and describing what they see or experience. P24 is initially more cautious and skeptical of the diorama and needs help to relax and understand what we are proposing.

We now look at accessibility, engagement, and learning during exploration and playing with the diorama via participant observations and feedback.

7.4.2 Exploration

Several similarities were observed in participants' exploration behaviors. A few participants described the elements they saw, such as in P6, P8, and P20, while others pointed at them and named them, as seen in P11 and P25. Many participants interacted with the wind, expressing enjoyment, surprise, or fascination with it, as evidenced in P7, P8, P11, P15, P16, and P25. Some participants explored the exhibit independently, as observed in P15 and P21, while others needed some prompting, such as in P11 and P19. P19 mentioned, "I am confused with the mouse" and later on highlighted when the fan was activated "as if it was the wind of nature." Ultimately, P24 expressed curiosity about the exhibit's purpose or mechanisms.

7.4.3 Independence and Accessibility

Most participants were able to access the diorama and complete their assigned tasks independently. Nonetheless, some participants required different levels of assistance to complete the game. Three participants (P15, P18, P25) were found to be primarily independent but required some form of guidance or assistance, such as specifying where to place a statuette or correcting the placement of a tag on the reader. One participant required scaffolding to complete the game (P21), and another needed help to start (P24).

7.4.4 Understanding and Learning

Participants showed a good understanding of the feedback provided in the game, either through sound or light. Some participants found the light feedback more immediate and noticeable than the sound feedback. When prompted, P25 said, "*It's not right because red means mistake*". Several participants used the feedback to correct their following answer, while others understood that the green light meant a correct answer and moved to the next spot. P6 says when playing, "One reindeer doesn't eat another reindeer. That doesn't make sense." One participant (P24) required scaffolding to understand the game. The vibration was the least noticeable. Participants could feel it when touching the statuettes during the game's feedback.

7.4.5 Gaming Experience

Most participants demonstrated an understanding of right and wrong answers by saying out loud what was going to happen, before waiting for the matching game feedback. P25 is sure about her answers and proud to get them right, saying: "You see?!?" Two participants (P21 and P24) needed help playing the game. P16 explained the gaming experience "I didn't know if it was correct, but I wanted to try. The light told me it was right."

7.4.6 Emotions and Engagement

Participants exhibited a range of emotions during gameplay. P6, P18, and P25 were surprised and enthusiastic, with P6 expressing excitement at discovering new features "I really liked the box, did you know?" P7, P8, P11, P19, and P24 smiled during gameplay, with P11 smiling specifically at the feedback, P19 while playing with the reindeer statuette, and P24 while discovering what the box did. P20 was generally serious, while P21 was curious and spent time looking closely at the objects.

7.4.7 Preferences

We asked participants to freely choose which solution they would like to use to learn more about the museum content. They had five alternatives, three high-tech (Museum app, Augmented Reality app, and the MSD) and two low-tech (printed easy-to-read text and AAC pictograms). MSD was the second preference of 5 participants (P11, P16, P18, P24, P25), the third preference of 3 participants (P6, P7, P19), and the fourth (P20 and P15) and last (P8 and P21) of two. When placed as second or third place, the MSD was always chosen after a high-tech solution, proving the engagement and interest in technology by people with intellectual disabilities.

7.4.8 Interview

After each one-on-one session, the participants were asked about what they saw without any extra prompt, they were free to express what they remembered. They all described the box and various animals, the reindeer and the wolves.

P16 mentioned "stickers" indicating the game alternatives glued on top of the box, while P8 and P20 provided detailed descriptions of the LEDs, fan, and wind, as well as their interactions with the box. P21 noted the presence of "fake moss," and P19 mentioned the "reindeer and wolf family."

We asked participants to describe their experience with the MSD in detail and prompted, if necessary, with the following questions: were there any noises or sounds? Did you have something to read? Were there any pictures? Were there any lights? Could you do something with the box? Many participants mentioned lights that turned green when they gave a correct answer and red when they gave an incorrect answer. Some participants also reported hearing animal sounds, such as the wolf howling or the reindeer making noise. Several participants described feeling the wind on their hands or seeing leaves move when they touched a specific box area. Participants appeared engaged and enjoyed interacting with the various elements, such as guessing which animals the wolf and reindeer should eat. However, there were also some differences in their experiences, such as one participant who reported not hearing any noises (P16) and another who did not see any lights in the box (P24).

Lastly, during the interview, the educators asked about the participants' favorite technology. A few participants said they enjoyed the tablet (with the museum or AR app) and the easy-to-read texts. P7, P11, P15, P18, P19, and P21 highlighted the box and its features. P8 answered, "I liked the pictures," which could be related to any of the alternatives they had in the hall. Additionally, one participant (P16) noted that he liked everything.

7.5 Conclusions

This study aimed to propose and evaluate the effectiveness of an MSD designed to enhance accessibility and interaction in the museum environment. The MSD was an innovative and inclusive way for people with intellectual disabilities to learn about the museum content, providing participants with multisensory experiences that allow for interactive and fun informal learning. Nevertheless, the study had limitations, such as noise inside the museum that disturbed the audio feedback experience and the museum hall with stimuli everywhere.

This study laid the groundwork for exploring RQ 1.3 and addressed RQ 3.1: "How do people with intellectual disabilities perceive and engage with a multisensory diorama?". The response is summarized in several main points:

- **Diverse Engagement Methods**: Participants engaged with the multisensory diorama using various methods, including haptic and audio feedback.

The diverse methods underscored the importance of designing interactive experiences that cater to multiple senses and learning styles. By allowing individuals to touch, see, and hear different elements of the diorama, the design effectively facilitated a more inclusive and accessible learning environment.

- **Adaptive Interaction Design for Accessibility**: The study revealed that while many participants could independently interact with the diorama, some required scaffolding. Designing interactive experiences that can be adjusted or personalized on the fly can help ensure that all participants can engage fully and independently with educational content regardless of their abilities.

- **Educational Engagement Through Feedback Mechanisms**: The MSD's use of feedback mechanisms, such as sound, light, and vibration, played a crucial role in reinforcing learning and aiding understanding. This multisensory feedback approach is particularly effective for individuals with intellectual disabilities, as it can cater to different sensory preferences and learning styles.

- **Learning Reinforcement via Interactive Games**: Incorporating a matching game within the diorama proved to be an engaging way to reinforce learning about the food chain. This interactive element made the learning experience more enjoyable and helped solidify the participants' understanding of the content. Games and interactive challenges can thus serve as powerful tools in informal learning by providing a hands-on experience that enhances comprehension and retention.

- **Emotional Engagement**: The study observed a wide range of emotional responses to the diorama, from surprise and enthusiasm to curiosity. This emotional engagement is key to creating memorable experiences.

Future work should focus on evaluating new multisensory feedback and increasing speakers' volume. Overall, the results of this study suggest that the MSD successfully engaged participants and elicited a range of responses and behaviors, making it a promising approach for enhancing museum learning experiences.

This chapter started Part III of this doctoral dissertation, which explores how multisensoriality and creativity can be fostered with technology. The following chapter, Electronic Making and Creative Expression, will continue the exploration of Creativity and Multisensory Integration by integrating both topics to enable self-representation.

8

Electronic Making and Creative Expression

This chapter builds on the growing recognition of the importance of inclusive and accessible technology design, where there is a significant opportunity to go beyond functional support and include creative expression. The EmpowerBox effort exemplifies this shift by offering an opportunity for people with intellectual disabilities to express themselves by creating a Multisensory Self-Representation Box. This approach is strongly influenced by the principles of the maker movement, electronics, and contemporary educational methods, which encourage a hands-on, exploratory approach to learning and creation.

Situated as the second chapter in Part III of this doctoral dissertation. It is one of the chapters that provide content to answer RQ 1.3 (*How can we use technology to involve people with intellectual disabilities in creative and multisensory experiences?*) and to address RQ 3.2 (*How can making an electronic multisensory personalized box allow creative expressions by people with intellectual disabilities?*). This work focuses on creative expression and multisensory experiences, emphasizing the importance of enabling participants to express themselves and the possibility of communicating with others using AAC and haptic feedback. The initiative was executed in Italy in collaboration with Anffas, and it reflects a collaborative effort to empower people with intellectual disabilities to communicate, acquire knowledge, and create in ways that are relevant to their experiences and perspectives.

This work provides several contributions to HCI. It includes the conception, design, and evaluation of the EmpowerBox approach, demonstrates how a multisensory box can foster creativity, communication, and social interaction among people with intellectual disabilities, and provides the broader societal benefits of promoting inclusive and creative collaboration.

8.1 Introduction

In recent years, there has been a growing recognition of the importance of inclusive and accessible approaches to technology and design [222]. This paradigm shift has extended to various domains, including education, communication, and creativity, with a heightened emphasis on enabling individuals from diverse backgrounds to express themselves and engage meaningfully with their surroundings. One significant area where this shift has taken root is in the domain of assistive technology, where innovative solutions are sought to empower individuals with intellectual disabilities to communicate, learn, and create in ways that resonate with their individual experiences and perspectives [287].

Individuals with intellectual disabilities often face distinct challenges in conventional modes of communication and expression due to varied cognitive, sensory, and motor abilities. While beneficial, traditional assistive technologies have predominantly focused on functional aspects of communication, often overlooking these individuals' creative and expressive needs. The EmpowerBox initiative recognizes the inherent value of enabling creative self-expression and aims to address this gap by providing an accessible and engaging platform.

This chapter introduces an innovative approach to support the making of an "EmpowerBox," a Multisensory Self-Representation box aimed at fostering self-expression and creativity among individuals with intellectual disabilities. Drawing inspiration from principles embedded in the maker movement, electronics, and contemporary learning methods, EmpowerBox emerges as the result of a collaborative initiative that transcends traditional communication and creative engagement boundaries. At its core lies a deep commitment to amplifying the voices of individuals who often navigate a world that struggles to accommodate their diverse modes of expression [282].

The distinctive feature of EmpowerBox is its multifaceted nature, strategically designed to engage the senses and facilitate holistic interaction. EmpowerBox creates a canvas through which participants can communicate their thoughts, feelings, and preferences by weaving together auditory, tactile, visual, and personal elements. While assistive technologies have made significant strides in addressing the various needs of individuals with disabilities [287], there remains an opportunity to expand their scope beyond functional support to encompass the realm of creative expression.

The motivation behind EmpowerBox springs from the desire to provide a platform for individuals with intellectual disabilities to transcend the limitations of conventional communication methods. Although a range of assistive technologies exists, a gap persists in empowering these individuals to express themselves and participate in creative endeavors actively [310]. EmpowerBox fills this void by embracing the ethos of the maker movement, which advocates for a hands-on, exploratory approach to learning and creating.

This chapter situates EmpowerBox at the intersection of several critical areas: the maker movement's philosophy of democratized creativity, electronics as a means to create interactive and personalized experiences, and contemporary learning methodologies that emphasize autonomy and collaboration. By merging these domains, EmpowerBox advances assistive technology discourse by promoting self-expression not merely as a functional outcome but as a profound pathway to self-discovery, communication, and shared understanding.

The primary contribution of this research is the conceptualization, design, and evaluation of the EmpowerBox approach. This chapter comprehensively explores the design principles, collaborative methodologies, and user-centric considerations underpinning EmpowerBox. It showcases how a multisensory box can serve as a catalyst for creativity, communication, and social interaction among individuals with intellectual disabilities. Furthermore, the study sheds light on the broader societal benefits of fostering inclusive and creative collaboration in a world that thrives on diversity.

The structure of this chapter is organized as follows: Section 8.2 explores the design philosophy and technical implementation of EmpowerBox, elucidating the integration of multisensory elements and personalized craftsmanship. Section 8.3 outlines the collaborative methodology adopted for EmpowerBox workshops, highlighting the iterative and participatory approach to engaging participants, the ethical considerations, and data storage. Section 8.4 details the empirical evaluation, capturing the qualitative insights. Section 8.5 discusses the implications of the study's findings, emphasizing the potential of assistive technology to reshape societal perceptions and attitudes. Section 8.6 introduces the limitations and outlines avenues for future research. Section 8.7 concludes the chapter by summarizing the contributions. Lastly, a review of relevant literature spanning the right to participation, technology to foster creativity and imagination, maker movement, and inclusive design was already introduced in Section 2.9.

8.2 Designing EmpowerBox

Recognizing the importance of storytelling in fostering self-discovery and self-expression, we launched EmpowerBox. We aimed to use technology and makerspaces to help people feel more included. Furthermore, we envisioned to use the power of creation to foster social connections.

8.2.1 Requirements

To successfully complete the project's main goals, the box's design had to adhere to a number of requirements. Requirements were provided in part by the literature, and in part by a brainstorming session we held with educators from an organization that assists people with intellectual disabilities. The educators, in particular, expressed the need for nonverbal and minimally verbal people to explore communication in a new multisensory way. They also emphasized the importance of accessibility and a short learning curve in order to keep them interested and engaged. They suggested using colors and accessible materials and considering the need for scaffolding throughout the activity.

- **Customization for creativity and self-expression**: a central purpose of the box is to promote creativity and self-expression. To do so, the box has to be a canvas for personal expression, allowing individuals to convey their thoughts, emotions, and identity through creative means [87, 262], empowering users to express their individual experiences and perspectives through customization and creative engagement.

- **Facilitating social interaction**: the box's role as a facilitator of communication and interpersonal relationships had to be emphasized in the conceptualization. Its design was intended to promote social interaction and the formation of bonds between people. To operationalize this requirement, the box itself had to be able to interact with other boxes.

- **Short learning curve**: the interior circuitry of the box had to be understandable. This design method was created with people with intellectual disabilities in mind, ensuring that the functional connectivity of electronic components could be easily understood and remembered [87, 262].

- **Low entrance barriers**: the creation process had to be accessible. To enable this, the box had to use clear colors to aid comprehension, provide clear affordance [87], and components had to be large enough to be manageable while reducing the need for precision and dexterity [137, 138, 146].

- **Replicability**: following the quest of Ellis et al. [87] to make technology more affordable, the box needed to be easily replicable. This necessitated meticulous material selection, with an emphasis on affordability and accessibility. The assembly procedure was also designed to be quick, with the goal of publicly sharing detailed assembly instructions to reach a wider audience.

8.2.2 Structural Design

The physical structure of EmpowerBox was envisioned to accommodate both its functional components and the user's creative expression. The chosen container was a 15.5cm x 10.5cm x 2.5cm (or 6.1" x 4.1" x 1") cardboard box with an open top that effectively divided the space into two levels while connecting them. The upper level functioned as a conceptual platform for artistic endeavors, while the lower internal level housed the electronic circuits. The interactive button was strategically placed on the front, allowing participants to switch EmpowerBox on or off. The EmpowerBox structure can be found on Fig. 8.2, and the disassembled kit can be found on the top-right side of Fig. 8.1a.

(a) Starter Kit (b) Internal Button (c) Battery Holders (d) Greeting Feature (e) Greeting Battery

Figure 8.1. EmpowerBox starter kit and internal components.

Internally, the container was designed to house a variety of electronic components. Its inner sides provided space for the main interactive button circuit (Fig. 8.1b), the upper-level battery holders (Fig. 8.1c), the greeting feature conductive plates and vibromotor (Fig. 8.1d), and the greeting feature battery (Fig. 8.1e). The battery holders were strategically positioned on the foldable inner sides, making it easy to change batteries as needed. We used CR2032 batteries to make the project affordable while keeping the box size small.

The upper-level components were powered by up to three batteries, and the greeting feature required one additional battery to run independently of the load required by the upper-level components. The upper-level batteries were linked to the upper part through separate negative and positive rails. These rails were built with conductive tape that was color-coded in red (positive) and blue (negative). An on/off switch was installed between the batteries and rails to provide easy power control.

To emphasize the **greeting feature**, the box's outside was furnished with four conductive tape strips. Two of these were connected to the specialized battery as power and ground connectors. The other two conductive tape plates were linked to a vibromotor inside the container. The greeting concept entailed bringing two EmpowerBoxes into contact, allowing the activation of the batteries to simulate a "handshake" while the vibratory motor was activated in both boxes. We reserved space on the box's bottom to attach printed **pictures and/or Augmentative and Alternative Communication (AAC) pictograms** chosen by each participant.

We prepared a starter kit containing the EmpowerBox, a frame, EVA (ethylene-vinyl acetate) boards available in different colors, and the conductive tapes to connect the components from the EVA to the box. The EVA board made the enclosure of the upper surface. Two different rails had to be positioned on the underside of the EVA board: a positive rail (red) and a negative rail (blue), each with its own conductive tape. This color palette was driven by the enclosure rails. Colors were used to help participants use components and connect them with more independence, not requiring electronic knowledge or reading abilities. The EVA board's architecture permitted secure component insertion, exposing functional parts while keeping component pins discretely beneath the surface.

8.2.3 Illustrative Journey: EmpowerBox in Action

The user is presented with several scenarios for interacting with EmpowerBox, including the ability to build it from scratch or make only the upper portion. This adaptable strategy accommodates different skills without simply removing challenges. Since our storytellers interacted with an intermediate version of the box in this study, we will now describe a typical user journey (Fig. 8.3).

In this scenario, the box has the internal circuit already put in place, but the EVA board is empty. The storyteller's first step is to identify which aspects of themselves they want to highlight by collecting pictures and AAC pictograms. They acquire the necessary decorations before deciding which element will enhance their story and picking related electronic components (Fig. 8.3a). After that, the storyteller selects a color for the EVA board (Fig. 8.3b). Before arrang-

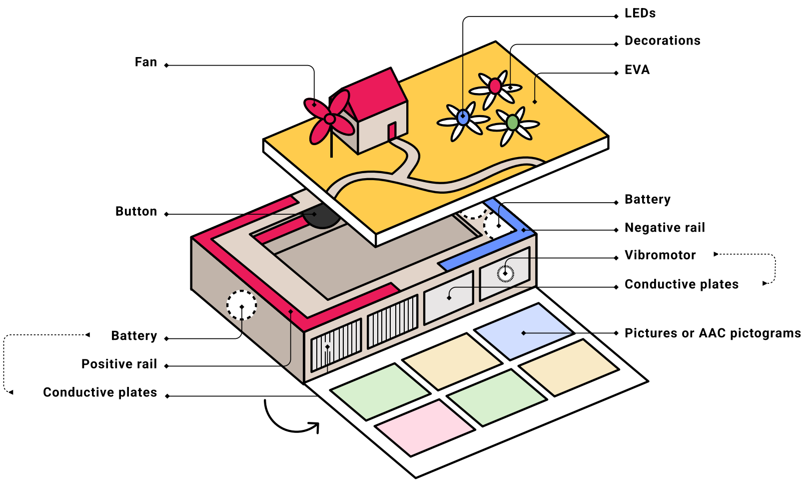
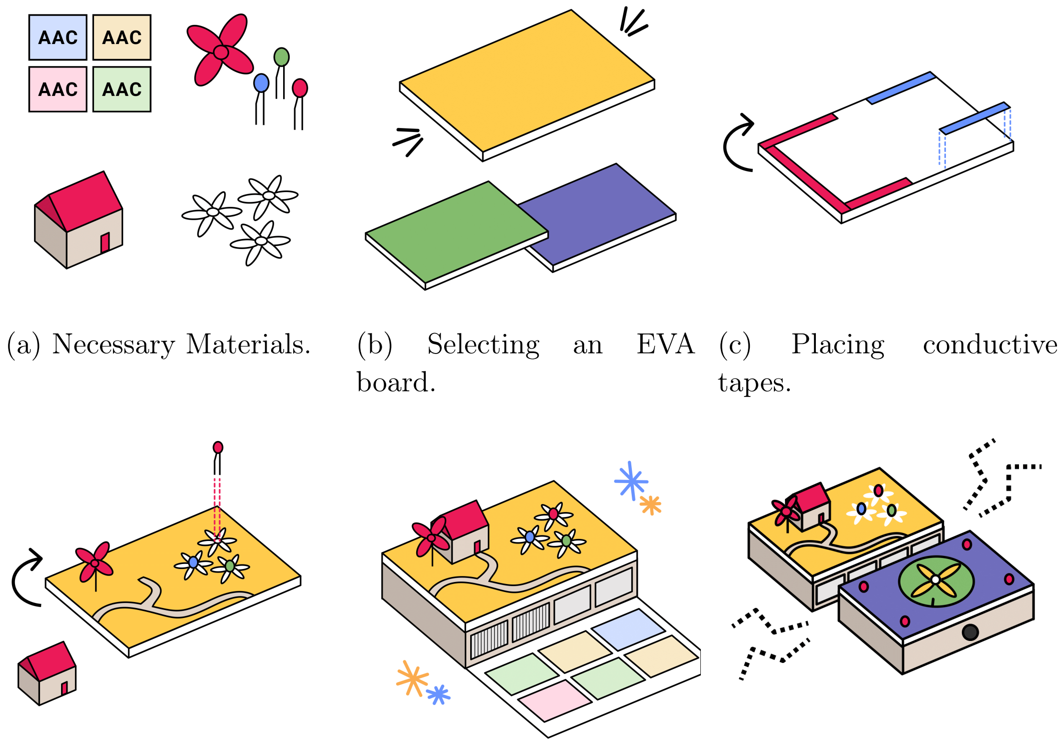


Figure 8.2. EmpowerBox structure in detail with the description of each content.

ing decorations and components, they carefully place conductive strips on one side to avoid contact between blue and red strips (Fig. 8.3c). With this circuit part in place, the storyteller can move on to figuring out how to effectively arrange the various elements. Decorations are glued to the EVA board with the help of the frame, limiting their canvas, and electronic components are inserted on top of the board. The pins of these components are bent and conductive taped to the positive and negative rails (Fig. 8.3d). When the EVA board is completed, it is attached to the box. Power pours through the components when the button is pressed, enchanting the box. The storyteller can enhance communication by inserting pictures or AAC pictograms expressing their interests on the bottom surface. This makes the box a means for multisensory self-presentation to others (Fig. 8.3e). To increase the social aspect, two storytellers can make the boxes come into contact, which results in a reciprocal "handshake" and a corresponding vibration — a subtle celebration of shared connection that we call the greeting feature (Fig. 8.3f).



(a) Necessary Materials. (b) Selecting an EVA board. (c) Placing conductive tapes.

(d) Placing decorations. (e) Connecting and turning the box on. (f) Greeting feature.

Figure 8.3. Storyboard of the possible use of EmpowerBox.

8.3 Methodology

8.3.1 Rationale and goal

The methodology employed in this study aims to evaluate the effectiveness and impact of the EmpowerBox project in fostering self-expression, creativity, and social interaction among individuals with intellectual disabilities. The rationale behind this methodology is to provide a structured approach for assessing how well EmpowerBox meets its intended objectives and to gain insights into its usability and user experiences. Additionally, this methodology seeks to identify any potential challenges or areas for improvement in the design and implementation of EmpowerBox.

8.3.2 Participants

In this research, we engaged with diverse participants who brought their unique characteristics and needs to our study. Participants were all members of a local association in Italy that promotes the inclusion of people with intellectual disabilities. We worked on this project in 2022. After proposing the project to the association's educators, they began the recruitment process: the chosen participants were those who the educators felt would benefit the most from a self-expression activity. They were asked if they wanted to participate in the project and were informed that they could withdraw anytime. There was no financial compensation. However, the activity was part of their technology workshops, and each participant received their EmpowerBox as a gift. The Table 8.1 below provides a comprehensive overview of our participants, including their demographic information[1] and diagnostic details provided by the association after obtaining their permission:

Table 8.1. Participants' demographic and diagnostic information.

PID	Gender	Age Range	Country	Oral Communication	Disabilities
P6	Woman	20-25	Italy	Verbal	Moderate Intellectual Disabilities
P8	Man	30-35	Italy	Verbal	Moderate Intellectual Disabilities and Epilepsy
P14	Woman	20-25	Italy	Minimally Verbal	Mild Intellectual Disabilities
P15	Woman	50-55	Italy	Verbal	Moderate Intellectual Disabilities
P18	Woman	45-50	Italy	Minimally Verbal	Severe Intellectual Disabilities
P20	Man	45-50	Italy	Verbal	Mild Intellectual Disabilities
P24	Woman	50-55	Italy	Minimally Verbal	Moderate Intellectual Disabilities and Down Syndrome
P26	Woman	25-30	Italy	Non-verbal	Moderate Intellectual Disabilities and Down Syndrome

This diverse group of participants underscores the importance of tailoring our approach and technology, EmpowerBox, to meet their specific needs and preferences. Throughout the study, we collaborated closely with the participants, respecting their individuality and striving to enhance their self-expression and communication abilities.

8.3.3 Procedure

The methodology involved a series of steps and procedures (before, during and after RV5) to achieve the aforementioned goals:

We initiated our research with a sequence of meetings (A1) involving all project authors—three computer science researchers and one special needs educator—two stakeholders, a psychologist, and a support worker. These meetings

[1]Country name was hidden for the review process.

Table 8.2. Summary of activities before, during, and after the workshop.

AID	Activity name	Period	Members	Description
A1	Meetings	Before	All authors	Planning the activities, allocated time, and materials needed
A2	Buying materials	Before	Researchers	Buying materials from different suppliers and testing them
A3	Prototyping	Before	Researchers	Designing several prototypes focusing on an affordable and accessible workshop
A4	Designing	Before	Researchers	Designing a final version of EmpowerBox using all areas of the box to display information, building starter kits, and examples
A5	Preparing participants	Before	Educator and participants	Asking participants' contributions about their favorite items and filtering sensitive information
A6	Learning and expressing preferences	During	All authors and participants	Participants were learning about the electronic components and expressed their preferences
A7	EmpowerBox example	During	Researcher and participants	Showing an EmpowerBox example and understanding participants' interests
A8	AAC representation	During	All authors and participants	Preparing an AAC representation, printing, folding, and gluing under EmpowerBox
A9	Making EmpowerBox	During	All authors and participants	Participants created their boxes with the help of the facilitators as needed
A10	EmpowerBox interaction	During	All authors and participants	Participants were showing their boxes, communicating, and discovering the greeting feature
A11	Interview	After	Educator and participants	Understanding participants' perception after a few days

served as a platform to organize project activities, allocate time effectively, and determine the necessary materials for the study. During these sessions, we proposed activities and ways in which technology could assist participants in self-representing their identity while benefiting from creative expression. Further, materials for building the structure of the EmpowerBox were sourced from various suppliers (A2), focusing on testing their suitability for the project's needs, accounting for usability and accessibility. The first and second authors selected the materials. This phase was crucial in ensuring that the materials selected were accessible, affordable, and met the specific requirements of the participants. With the materials available in the lab, several prototypes (A3) of EmpowerBox were created, with a strong emphasis on designing an inclusive and accessible workshop for participants. These prototypes allowed us to refine the design and functionality of the box to maximize its usability and engagement potential.

After several trials and internal discussions within the multidisciplinary research group, we designed the final version (A4) of EmpowerBox, considering the many ways the box could be used to display information for information display. Starter kits, accessible material, and examples were prepared to aid participants in their creative journey. The design was meticulously crafted to ensure that it catered to the diverse needs and preferences of the participants. Before engaging participants in the project, the educator collected information (A5) from them while respecting their privacy and filtering sensitive data. This phase was critical in understanding each participant's preferences and which electronic components they would require. The educator asked each participant to take or bring pictures of 5 things they like, contextualizing that the pictures could be available in their house, their support center, or from objects, people, and activities that they like. The educator also asked each participant to bring one object to the institution, and they made activities with them.

After receiving the pictures and descriptions from the educator, we could imagine what would be the requirements from our participants. It could fit with the materials we already have, and if needed, we could improvise using the materials at the institution. We had two full days to conduct the in-person activities facilitated by the educator and a support worker who was taking care of the participant's needs. We started the activity by introducing the electronic components and exploring participants' preferences (A6) to ensure a personalized experience with EmpowerBox. We began by showing the LEDs (light-emitting diodes), one color at a time. We could see participants' reactions and asked for their favorite colors. We had green, blue, yellow, white, red, double-colors, and colorful (with different changing speeds) LEDs. We also introduce the fans with different propeller sizes and colors (blue, red, and black). Later, we introduced the vibromotor and quickly the buttons and the buzzer. Participants had access to accessible material about each component, and the printed material contained a title, picture, and easy-to-read description of what each piece of material does. This material could benefit the participants or support work to understand how each component works. A6 ensured a learning process, respecting participants' preferences so the boxes could reflect their individuality.

An example of how EmpowerBox could function was presented to participants to gauge their interests and expectations. This demonstration served as a starting point for participants to understand the possibilities and creative potential of the technology. The EmpowerBox example (A7), available in Fig. 8.4, displayed a box with winter and Christmas decorations. We did this session in October and soon participants would prepare for the holidays and the winter season. The first author started with his AAC pictograms pointing to his favorite things: sea and islands, parties and music, teaching, technology, traveling, and a QR-code redirecting to his website. Around and on the top of the box, the researcher placed a synthetic grass simulation and a red decoration. On the upper level, the box had two cartoons, two bells, a leaf twig, and as electronics, a fan, and one red and one green LED.

The following step was related to the AAC representation. Based on the images we received, we requested each participant approve or suggest changes to an AAC grid (A8) meant to represent what they liked. The grid had 6 squared spaces, 5 for AAC pictograms or pictures, and one for their personal information (name, age, city, contact) or a QR code to be scanned by their new friends. Participants could express themselves verbally by pointing, writing, or with emotions and body language, approving how they want to be represented. The educator and support worker were essential to help us avoid bias and stick to the participants' favorite hobbies. We printed, folded, and glued each AAC sheet under each EmpowerBox. This AAC system aimed to enhance the participants' ability to convey their thoughts and emotions to others.

We started the creative-making activity (A9) by providing printed images of participants' favorite objects, people, animals, and places. They also had access to magazines and ornaments to inspire new decoration possibilities. Participants actively created their EmpowerBoxes, receiving assistance from the project authors or the support worker as needed. This hands-on phase allowed participants to take ownership of their creations, fostering a sense of pride and accomplishment. Once the boxes were completed, participants shared their boxes (A10), communicated with others about their design, and explored the handshaking feature, fostering interaction and self-expression. The impact of EmpowerBox on the willingness of participants to communicate and share their interests with

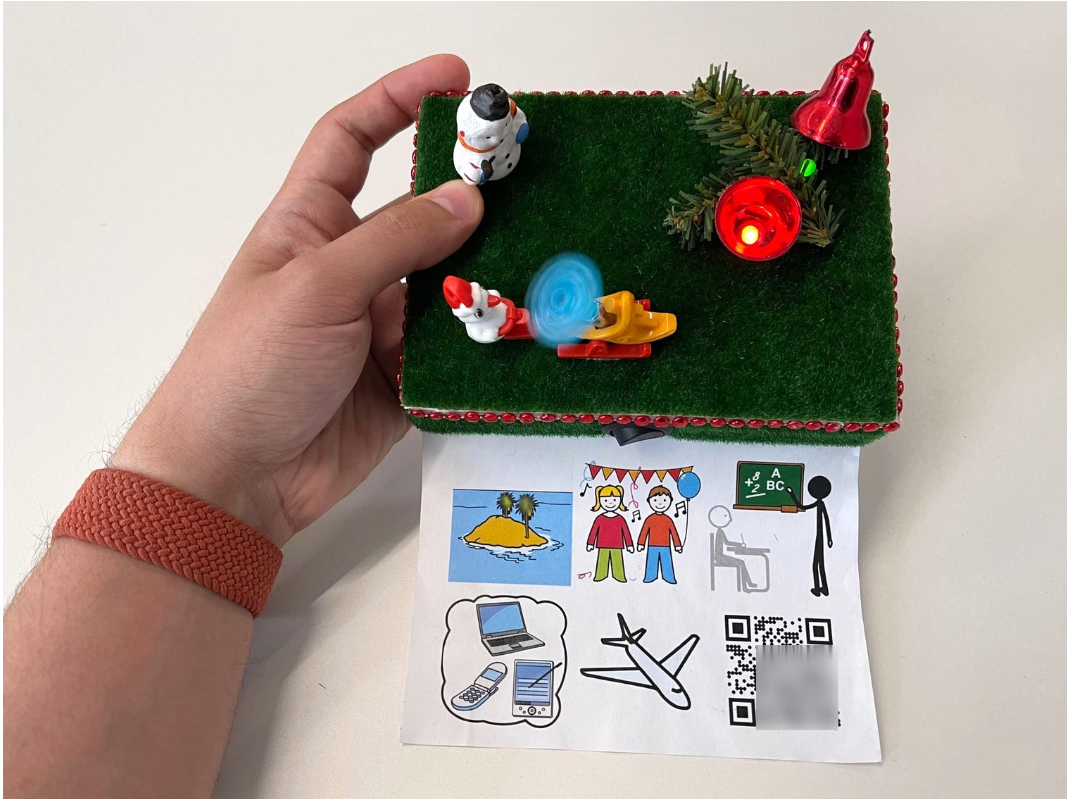


Figure 8.4. EmpowerBox example.

their peers as a means to boost their social interaction skills.

After a week of using EmpowerBox, participants were interviewed (A11) by the educators to understand their perceptions and collect feedback on their experiences. These interviews provided valuable insights into the effectiveness of EmpowerBox in fostering self-expression, creativity, and social interaction. The interview script consisted of the following questions:

1. Describe your box.

2. How did you make the box?

   (a) Did you participate in its creation?

   (b) What decisions did you make?

   (c) Which parts did you not contribute to?

3. Try using the box.

4. What purpose do you think the box serves?
5. Try looking under the box (if not done already):
   (a) What do the images represent?
   (b) Why were they placed there?
6. What are your thoughts on this box? What aspect do you like most about it?

8.3.4 Ethical considerations and data storage

Ethical considerations and data storage were paramount throughout our research endeavor. We maintained a strict commitment to safeguarding the privacy and dignity of our participants, recognizing the need to handle their personal information with utmost care. The educator was pivotal in ensuring that any sensitive data collected, such as personal preferences and communication modes, was treated confidentially and respectfully. Data storage was handled securely, with all electronic records encrypted locally and stored on password-protected devices.

Additionally, we obtained informed consent from the participants or their legal guardians, explaining the purpose and scope of the project, the data collection process, and how their information would be used. We emphasized that participation was voluntary, and participants could withdraw at any time without consequences. We also maintained open lines of communication with the support workers and caregivers to address any concerns or special requirements related to the participants' well-being.

Our commitment to ethical conduct extended to the design and use of EmpowerBox itself. We ensured that the technology was designed to empower and enhance the participants' self-expression and communication abilities, while also respecting their individuality and preferences. The AAC grids were customized based on participant input, and we took great care to avoid any bias or imposition of our own preferences during the creative-making activity. Participants were the protagonists of the process, and the resulting EmpowerBox represented the identity they felt like sharing with others.

8.4 Results

The authors developed Activities A1 to A4, drawing upon their prior experiences with participants, insights from previous research papers involving individuals with intellectual disabilities, an understanding of their needs, and a comprehensive literature review. The fifth activity started with the involvement of participants, and this section will offer a comprehensive account of it.

8.4.1 Preparing participants

During the preparation phase of the workshop, the educator engaged with the participants to understand and gather information about their favorite hobbies and items. Participants independently brought their cherished pictures and objects to the support center, either on their own or with the assistance of their guardians or support workers. In a group session facilitated by the educator, printed pictures representing each participant's likes were presented, and the participants were asked to identify which pictures belonged to them.

Among the participants, P26 demonstrated recognition of the pictures associated with her preferences. Using gestures, she indicated that her mother had assisted her in this process. We can cluster their main interest in the following categories: Entertainment and Media, Electronics and Technology, Food and Drinks, Miscellaneous, Pets, and Social Relationships.

8.4.2 Learning

The in-person activities started with the researcher introducing various electronic components (A6). Participants expressed amazement at the LEDs, and when the researcher activated a blinking light that slowly changed colors, the participants voiced their liking for it. Participant P14 exclaimed, "How beautiful! I like it very much!". Furthermore, the participants showed an understanding of the colors, either by naming them or pointing to similar colors in their surroundings.

The researcher then focused on propellers, and P6 quickly identified them as fans. Some participants, like P20, appeared a bit scared, while others, like P18, touched the propellers and described the sensation. P24 expressed her liking by putting her hand up. P8 observed it with interest and eventually tried to touch it. Preferences for propeller colors were also discussed and were varied; three participants preferred the blue propellers, three preferred red, and two preferred the black color.

The study further explored the use of a vibromotor. P15 laughed and expressed her liking for it, while P20 initially seemed scared but later found it enjoyable with the researcher's guidance. P18 described the sensation as ticklish. P26 liked it so much that she extended her other hand to feel the vibration. P6 expressed concerns about potential harm but eventually realized it was safe and found it enjoyable. P14 praised the vibromotor, describing it as pretty and nice, while P8, initially upset for other reasons, showed some interest but without strong enthusiasm. P14 highlighted her favorite components in order: vibration, light, and propeller.

Participants were introduced to other electronic components as the workshop progressed, including buttons and a buzzer. The buzzer's sound was generally perceived as annoying, unlike the pleasant experience of listening to music. Participants' learning experiences were facilitated by the availability of easy-to-read materials, interaction with familiar researchers, and support from their educators and support workers. The learning curve varied among participants, with theory and practice applied simultaneously to expedite the learning process. The tailored approach, where participants' preferences were considered, led to positive engagement and responses during the workshop.

These results highlight the participants' active engagement and positive reactions when learning about the main multisensory components of the EmpowerBox, showcasing the effectiveness of the approach in fostering self-expression among individuals with intellectual disabilities and how informal learning naturally took place.

8.4.3 Introducing EmpowerBox

The introduction of the EmpowerBox example (Fig. 8.4) yielded various responses and interactions among the participants, reflecting their unique perspectives and engagement with the multisensory box. Laughter and comments were common, with one participant (P6) expressing enthusiasm by stating, "I like Christmas, with this box I can make light and make the wind come," to which another participant (P20) praised the researcher, "What a genius you are." Participant P15 remarked, "How beautiful," showing appreciation for the box's aesthetic appeal.

The researcher then proceeded to involve participants in understanding and operating the box. P15 asked for help to turn on the box, and the researcher continued to pass the box to others. P18's reaction was surprised, exclaiming, "Ah gosh, my goodness!" and then saying, "I have to stay calm," while touching the grass element. P26 successfully turned the box on and off with the researcher's guidance. P6 initially expressed uncertainty, saying, "I've never done this; what should I do? Ah, I have to push the button!" P24, on the other hand, smoothly pressed the button and expressed her interest with a simple "Hum, beautiful." P8 engaged with the box, showing curiosity and touching various elements but without particularly strong reactions.

The researcher revealed the box's contents, explaining, "This is my box, with the things I like. And here are the images of what I like to do" as they uncovered the AAC sheet beneath the box. P26 displayed a keen interest in understanding the researcher's preferences, especially focusing on the QR code. P6 demonstrated quick comprehension of the drawings and recognized the QR code's meaning. P24 also correctly interpreted the symbols, the participant associated the QR code with the COVID-19 Pass. P8, while able to read the symbols, seemed to concentrate more on the specific objects depicted rather than their meanings, viewing them as a list of objects. Finally, P14 displayed interest and an ability to understand the AAC pictograms present in the researcher's box. The box's content, including the AAC pictograms, decoration, and electronic components, elicited diverse responses, highlighting the individualized perception and preferences of individuals with intellectual disabilities.

8.4.4 Personalizing the AAC representation

In the workshop, we presented participants with their pre-chosen favorite items. One by one, the participants either gave their approval for us to include an image in their grid or we selected an AAC pictogram from ARASAAC that could accurately represent it, ensuring it was comprehensible to the majority of their peers. This phase served not only as an opportunity for researchers to connect with the participants but also as a means for them to become acquainted with each other while reviewing their favorite selections. Every picture or pictogram chosen for the grid conveyed a unique narrative about the participant, sparking fresh reactions and connections among their peers.

8.4.5 Sharing and Discovering

The workshop's purpose extended beyond creating personalized AAC representations; it also served as a platform for participants to connect, share, and discover each other's interests and passions. Participants engaged in various topics and interests that served as icebreakers and strengthened their connections. These included a shared passion for music, leading to the exchange of favorite songs and deepening mutual understanding. They also discussed their affinity for radio and

TV shows, sharing recommendations and opening the possibility of organizing group viewings. Participants showcased diverse hobbies and interests, such as big cars, basketball, and video games, offering opportunities for shared activities and outings. Culinary preferences were explored through favorite dishes, and participants bonded over cooking and enjoying meals together. Outdoor activities, personal belongings, pets, technology, books, seasonal preferences, dancing, art, drawings, photography, movies, and animated characters all contributed to the sense of intimacy among participants, fostering connections through shared interests and experiences.

8.4.6 Making EmpowerBox

The process of making EmpowerBox was a transformative journey for both the participants and the researchers involved in this collaborative initiative. This section details the process by which participants created their personalized EmpowerBoxes. It describes the participants' interactions with materials and their engagement in the making process.

Personalization through Color Selection

The journey of making EmpowerBox began with a seemingly simple yet profoundly significant step: personalization. Each participant was encouraged to select their favorite EVA color from a spectrum of choices to decorate their box with. This choice marked the first connection between the participants and their EmpowerBoxes, symbolizing the start of a deeply personal journey of self-expression. Further, the diversity in color preferences among the participants was striking. Some opted for vibrant reds and blues, while others favored more subtle pastel shades.

Curating Cherished Memories

With their selected EVA covers and the EmpowerBox starter kit in hand, participants faced a pivotal moment in the personalization process. A table adorned with photographs of their most cherished items awaited them. These images represented their favorite memories and provided a canvas for them to express themselves.

P8 eagerly shared their chosen photos with the educator, each image carrying a story and a piece of their identity. In contrast, some participants, like P6, initially struggled to find the images that resonated with them. However, with patience and support, they eventually discovered and selected images that truly spoke to their hearts.

This step underscored the importance of these visual representations in infusing each EmpowerBox with a unique identity, ensuring that the box would become a vessel of self-expression and communication for its creator.

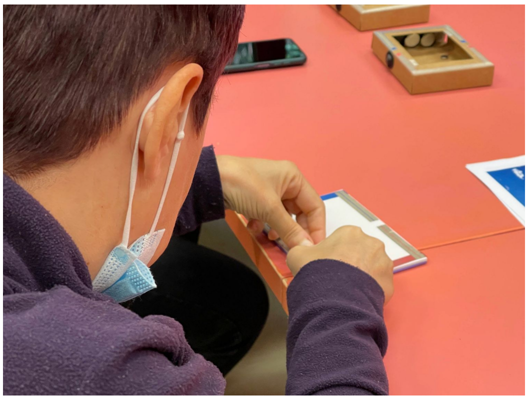
Multisensory Enhancement

The EmpowerBox project aimed to transcend conventional modes of expression by embracing multisensoriality. In this spirit, participants were given the opportunity to choose additional ornaments and decorations for their boxes. Stickers, fur, googly eyes, and other tactile elements were provided, allowing for a multisensory experience that would enhance the interactive potential of EmpowerBox.

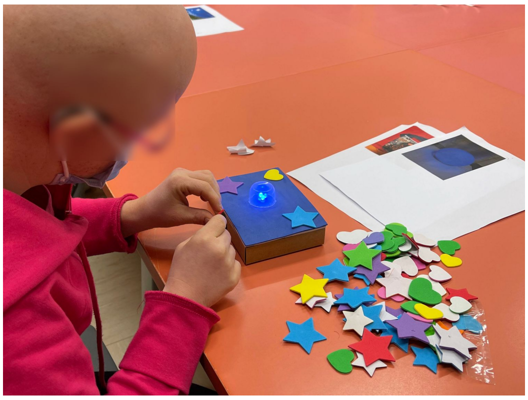
This process phase added depth and texture to the boxes, making them visually captivating and inviting to touch and explore. Participants were free to select items that resonated with them, further personalizing their creations.

Collaborative Construction

The actual construction of EmpowerBox was a collaborative effort, with participants receiving assistance as needed. The researchers played a crucial role in guiding and supporting the participants as they worked on attaching conductive tape, stickers, and other components to their boxes (see Figure 8.5).



(a) Participant P20.



(b) Participant P26.

Figure 8.5. Participants making their boxes: conductive tape sticking and decoration.

These interactions between participants and researchers deepened the sense of connection and trust in the workshop space. The researchers were no longer just observers and guides but became active partners in the creative journeys. This collaboration highlighted the adaptable nature of EmpowerBox, which could be tailored to cater to individual preferences and needs.

Emotions and Reflections

As the participants immersed themselves in the process of creating their EmpowerBoxes, a range of emotions were observed during the workshop. Excitement (P18: "Oh my holy goodness! I have to stay calm!”), curiosity (P6: "I've never done this, what should I do? Oh I have to push the button"), and joy (P6: “I like it a lot!” “Oh yes”) were palpable in the shape of facial expressions, the exchange of enthusiastic comments as the few reported above, and the lasting focus on the activity, as participants saw their unique visions come to life (P6: "I liked working. I like my box, it was beautiful!") and expressed their appreciation to other boxes too (P20: "I also like the other boxes"). Frustration and perseverance coexisted as they overcame challenges with determination and scaffolding.

The evolving relationship between participants and researchers was marked by a sense of mutual respect and understanding. The researchers, initially facilitators of the project, became partners in the collaborative design of EmpowerBox, sharing decisions and exploring alternatives, fostering an environment of inclusivity and empowerment. In these moments of making, participants expressed themselves and discovered new facets of their identity. The act of crafting their EmpowerBoxes was an act of self-discovery and self-empowerment, amplifying their voices and stories.

8.4.7 Enhanced Interaction and Empowerment

The EmpowerBox project fosters self-expression and creativity and catalyzes enhanced social interaction among participants. As they complete their personalized boxes, the participants experience a profound sense of ownership and pride in their creations. This newfound sense of agency and self-expression becomes a catalyst for meaningful interactions and connections. Here are some key observations of how participants interacted with each other and how the boxes enhanced their overall experience:

As participants work on their EmpowerBoxes, they begin to inspire each other. For example, P26, a non-verbal participant, shared her favorite song with P6 as they were finishing their EmpowerBox, using her iPod. This simple yet powerful interaction transcends conventional modes of communication, as participants had a link and an opportunity to discover common interests (Figure 8.6a).

(a) Participants interacting during the workshop: P26, a non-verbal participant, was showing her favorite song to P6.

(b) Participants were proud of their EmpowerBoxes and were posing for a picture with them.

Figure 8.6. Participants interacting and showing their EmpowerBox at the end of the workshop.

The multisensory nature of EmpowerBox leads to moments of excitement and delight during the project. For instance, when feathers are incorporated into P18's box, the sensory experience of seeing the lights activate elicits an enthusiastic "wow" from the participant. Similarly, P8's EmpowerBox, complete with a spinning propeller, becomes a source of fascination for others. These shared moments of wonderment create a sense of intimacy among participants.

The inclusive design of EmpowerBox extends beyond the immediate group of participants. When a member from another class enters the room and expresses a desire to join the project, they point to the completed box of P20 as inspiration. This demonstrates the project's potential to inspire and expand participation among individuals with intellectual disabilities, promoting a more profound sense of belonging and community.

After participants completed their boxes, they began testing each other's creations, leading to social moments of interaction and laughter. At this point, we introduced the greeting feature. A natural and spontaneous behavior emerged as some participants started saying "Hi" while connecting their boxes and feeling the vibration activate. P8 said, "*When I touch my friend's box it gives me tickles, it is funny*". Not initially designed as a primary function, this feature highlighted the participants' innate interest in communication and connection.

The EmpowerBox project not only provides a platform for self-expression and social interaction; it also serves as a powerful tool for learning and empowerment. Participants acquire technical skills in crafting their boxes and develop a deeper understanding of themselves and their preferences. This journey of self-discovery is facilitated by the project's multisensory approach, enabling participants to explore various modes of expression.

Through crafting personalized EmpowerBoxes, participants embarked on a journey of self-discovery. They reflect on their personalities and preferences, choosing elements that resonate with them. The boxes become a medium through which they communicate their individual experiences and perspectives to others. Participants proudly posed for a picture with their EmpowerBoxes as available in Figure 8.6b.

8.4.8 Interview after the workshop

In this section, we present the findings from interviews conducted with participants who have used the EmpowerBox. These interviews provide insights into their experiences, the creative process, and the impact of the multisensory box on their self-expression and communication.

Box Description

Participants described their personalized EmpowerBoxes, highlighting the diverse range of elements they included. P15's box featured a combination of a horror-themed figurine and a CD cover, reflecting their love for horror movies. P20's box was a tribute to superheroes and their pet, with added elements like vehicles, snacks, and superhero collectibles. P6's box prominently featured their favorite singer, along with a giant stuffed animal, a radio station, and an electronic device. P18's box showcased nature-inspired elements and mentioned their affinity for certain musicians. P8's box contained items like a TV channel, a timepiece, and accessories, referencing music artists.

Box Creation Process

Participants detailed their involvement in crafting their EmpowerBoxes and the decisions they made. P15 contributed elements like the horror figurine and stars, emphasizing their active role in the design. The researcher assisted in adding lights to enhance the sensory experience. P20 worked closely with the researcher, mentioning their choices of superheroes and snacks. They also highlighted the researcher's help with electronic components. P6 took charge of their box's creation, cutting and pasting images, and even attaching a necklace. While P6 made most decisions independently, the researchers offered support in certain tasks. P18, with assistance from the researchers, focused on choosing materials to decorate her box. P8 created their box with minimal assistance, and the researcher helped with technical aspects.

Using the Box

Participants discussed their experiences with the EmpowerBox's functionality. P15 initially encountered difficulties but eventually succeeded in activating the box's features. P20 demonstrated the box's capabilities, featuring a moving costume powered by a fan. P6 was delighted to showcase the colorful lights on their box, which they believed enhanced its aesthetic appeal. P18 experienced some initial challenges but ultimately found the box engaging. P8 shared their observation of the box's interactive components, indicating their engagement with its features.

Purpose of the Box

Participants provided insights into the perceived purpose of their EmpowerBoxes. P15 expressed that the box served as a means to share their creation with others. P20 considered it a decorative piece of furniture, emphasizing its visual appeal. P6 highlighted its role in showcasing their creativity to companions. P18 expressed a sense of pride in displaying their work to their mother. P8 saw the box as a way to share their creations with family members.

Interpretation of Images Under the Box

Participants were asked to interpret the images placed underneath their EmpowerBoxes. P15 related the images to their love for horror movies, emphasizing their preference for dark and intriguing themes. P20 simply appreciated the images for their beauty and connection to superheroes and their beloved dog. P6 saw the images as representations of things they liked, without delving into specific meanings. P18's response was more open-ended, expressing a general fondness for the images.

Overall Likability of the Box

Participants shared their feelings towards their EmpowerBoxes and what they liked about them. P15 expressed strong affection for their box, particularly the horror figurine with its captivating lights. P20 enjoyed their box but wanted to add music related to their favorite superhero characters. P6 had a profound attachment to their box, especially the elements related to the music artist. P18 expressed great enthusiasm for their box. P8 appreciated all the components in their box, including references to music artists.

8.5 Discussion

In this discussion section, we critically analyze the findings and implications of the EmpowerBox project, focusing on key themes such as storytelling, self-representation, social interaction, creativity, learning, collaboration, and social inclusivity. We examine the role of technology in supporting and encouraging these aspects and address challenges and opportunities uncovered during the project, drawing parallels to existing literature and studies discussed in Section 2.9.

8.5.1 The Power of Storytelling: Self-Representation and Social Interaction

The EmpowerBox project is fundamentally a multisensory narrative of self-expression and social interaction among individuals with intellectual disabilities. Similar to the findings in [164, 311], the act of storytelling plays a pivotal role in this project. Participants were encouraged to craft their EmpowerBoxes as unique narratives of their own lives, eliciting their preferences and interests. The results reflect the profound impact of storytelling in action, corroborating Meininger's emphasis on the connecting power of storytelling [193]. By self-representing through their chosen colors, images, and decorations, participants not only communicated their personal narratives but also invited others to engage with their stories, showcasing how the EmpowerBox empowers individuals to express themselves beyond specific intellectual abilities.

The integration of technology within the EmpowerBox amplified the storytelling experience. Multisensory components, such as LEDs, fans, and vibromotors, enriched these narratives by adding layers of sensory engagement, as multisensory approaches advocated by [87, 188, 320]. The blinking lights, spinning propellers, and tactile vibrations became integral elements in the participants' narratives, enhancing their ability to communicate emotions and preferences effectively.

Nonetheless, the journey of storytelling through EmpowerBox was not without its obstacles. Some participants initially faced challenges in finding images that resonated with them, highlighting the importance of patient support and guidance. Still, these challenges ultimately led to a deeper understanding of the participants' preferences and identities.

The EmpowerBox project allowed us, as researchers, to reflect on the transformative power of unconventional storytelling. It taught us that self-expression is not limited by the boundaries of conventional communication methods, a notion also evident in the work of Houben et al. [141]. EmpowerBox challenged us to think beyond words and embrace the diverse forms of expression that individuals can employ to tell their stories.

8.5.2 Crafting EmpowerBox: Creativity, Learning, and Collaboration

Making was central to the EmpowerBox project. This process intertwined creativity, learning, and collaboration in a unique and powerful way, echoing the sentiments of Taylor et al. [289] and Giles et al. [109] on the importance of makerspaces. Participants not only selected their favorite colors, images, and decorations but, more importantly, actively contributed to the creation of their EmpowerBoxes.

The concept of creativity took on various roles within the project. Participants showcased their creative expressions through their selections, making each EmpowerBox a work of art that reflected their unique tastes. Additionally, the researchers embraced creativity by adapting to participants' individual needs and preferences. This flexibility in the creative process allowed for the personalization and inclusivity that were integral to the project's success.

Learning was a fundamental aspect of the EmpowerBox journey. Participants not only acquired knowledge about the technical components of their boxes; they also cultivated a deeper understanding of themselves, honed crucial digital skills, and experienced an enhanced sense of self-confidence, ultimately leading to an increased feeling of empowerment. The incorporation of a multisensory approach, which involved hands-on participation and sensory feedback, greatly facilitated the learning process, as also observed in [188]. It was a journey of self-discovery, as participants reflected on their personalities and preferences while selecting and crafting their EmpowerBoxes.

Collaboration emerged as a powerful force within the project, fostering an environment of inclusivity and trust. The collaborative construction of EmpowerBoxes, with participants receiving assistance as needed, highlighted the adaptability of EmpowerBox, which could be tailored to cater to individual preferences and needs. Moreover, participants themselves engaged in collaborative interactions, inspiring and supporting each other during the project. This peer collaboration further strengthened the sense of community and mutual understanding among participants, demonstrating the project's potential to facilitate connections not only with researchers but also among the participants themselves, aligning with the findings in [28, 262].

As we reflect on the intersection of creativity, learning, and collaboration within EmpowerBox, we recognize the potential for future enhancements. We must continue to explore ways to scaffold learning, particularly for individuals with intellectual disabilities, as suggested by [87, 137]. Understanding how EmpowerBox can foster collaborative learning experiences can lead to even more profound outcomes. Challenges, such as finding the balance between autonomy and support, should be considered as we strive to improve this inclusive approach.

8.5.3 Cultivating Social Inclusivity

The EmpowerBox project, rooted in the principles of social inclusivity, has the potential to make a significant impact on the broader landscape of inclusive technology and community engagement. Building upon the foundation laid in the background section, where the importance of social inclusivity was highlighted, EmpowerBox serves as a tangible example of how technology can bridge gaps and foster connections.

By creating and sharing their personalized EmpowerBoxes, participants not only expressed themselves but also discovered common interests and passions. Shared hobbies, preferences, and experiences became the catalysts for meaningful interactions and connections among participants. The multisensory and collaborative nature of EmpowerBox allowed individuals with intellectual disabilities to actively participate in a community where their voices were heard and valued, reflecting the goals and impacts discussed in [164, 311].

EmpowerBox is a testament to the power of inclusion and empowerment. It challenges society's conventional notions of communication and self-expression for individuals with intellectual disabilities, advocating for a more inclusive and diverse world, as also discussed in [141, 193]. As we move forward, we must continue to explore the potential of projects to transform communities, enhance social inclusivity, and amplify the voices of those who have long been underrepresented.

8.5.4 Conceptualization, Design, and Evaluation of the EmpowerBox Approach

The EmpowerBox project's success is deeply rooted in its conceptualization, design, and evaluation. The project's inception involved a thoughtful consideration of the needs, preferences, and capabilities of individuals with intellectual disabilities. The conceptualization phase laid the foundation for a project that prioritized inclusivity and empowerment.

The design of EmpowerBox was a collaborative effort that required a deep understanding of both the technical aspects and the participants' unique requirements. The multisensory components, user-friendly interfaces, and adaptable design were critical elements that ensured the project's accessibility and effectiveness.

The evaluation of EmpowerBox was a continuous process that involved gathering participant feedback and making iterative improvements. We employed rigorous evaluation methodologies to assess the project's impact on self-expression, learning, and social inclusivity across emotional, interactional, and ecological dimensions. These dimensions encompassed participant well-being, self-expression, social interaction, collaboration, as well as the project's impact on engagement. Additionally, this evaluation approach aided in identifying both challenges and opportunities for further improvement, in line with the approaches suggested in [28, 262].

8.6 Limitations and Future Work

The study primarily concentrated on short-term outcomes and participant experiences during the EmpowerBox project. Some participants initially encountered technical challenges when interacting with the multisensory components of the EmpowerBox. While these issues were expected and addressed with timely support, it is crucial to acknowledge the importance of the accessibility of electronic components and the workshops. This includes refining user interfaces, providing clearer instructions, and appropriate scaffolding to ensure that EmpowerBox remains inclusive for individuals with diverse needs dealing with different degrees or types of intellectual disabilities, and allowing us to explore and analyze differences in responses.

Ongoing efforts to ensure the ethical conduct of research involving individuals with intellectual disabilities are imperative. While ethical guidelines were diligently followed throughout the study, it is essential to acknowledge the potential for bias or misinterpretation in our understanding of participant responses. Additionally, involving participants in the co-design of research protocols can help mitigate potential ethical concerns. Future work should include continued ethical reviews and exploring best practices for safeguarding the autonomy and dignity of participants.

While the study emphasized individual experiences, it did not extensively explore the broader community impact of the EmpowerBox project. Future research should incorporate longitudinal studies that track participants' progress and engagement with their EmpowerBoxes over an extended period to gain a more comprehensive understanding. This will enable us to assess the enduring impact of projects like EmpowerBox on individuals with intellectual disabilities. Future work should consider conducting assessments of how projects like EmpowerBox influence communities, institutions, and the perception of intellectual disabilities. This could involve gathering feedback from people with intellectual disabilities, support workers, educators, and family members to gauge the project's broader societal implications.

8.7 Conclusions

The EmpowerBox project represents a significant step toward fostering self-expression, communication, and social inclusivity among individuals with intellectual disabilities. This research chapter has presented the design and creative making of EmpowerBox, a multisensory technology-enhanced box that empowers participants to create personalized and multisensory narratives of their lives, preferences, and interests. Through a series of activities, participants actively crafted their EmpowerBoxes, integrating sensory components to enrich their narratives, enabling them to express their emotions and preferences.

The creative, learning, and collaborative aspects of EmpowerBox underscore its potential to empower individuals with intellectual disabilities. By combining storytelling with the ethos of the maker movement, we contribute to filling an existing gap in assistive technology for creativity. The project allowed participants to explore their creativity, acquire technical skills, and collaborate with researchers in a supportive and inclusive environment. It challenged conventional notions of communication and self-expression, advocating for diverse forms of expression that transcend traditional boundaries.

This study laid the groundwork for exploring RQ 1.3 and addressed RQ 3.2: "How can making an electronic multisensory personalized box allow creative expressions by people with intellectual disabilities?". The response is summarized in several main points:

- **Customization and Personal Expression**: EmpowerBox allows users to customize their boxes with personal images, decorations, and electronic components, enabling a unique form of self-expression. This customization goes beyond simple decoration; it allows individuals to tell their stories, share their interests, and express their identities in a tangible, creative form. Participants create a multisensory representation of their personal narratives by selecting elements that resonate with them.

- **Sensory Engagement and Communication**: Including multisensory elements (such as LED lights, fans, vibromotors, and tactile materials) in EmpowerBox provides a rich sensory experience that supports non-verbal forms of expression and communication. These elements enhance the boxes' aesthetic appeal and allow users to communicate through visual, auditory, and tactile stimuli.

- **Social Interaction through Shared Activities**: The process of creating EmpowerBox facilitates social interaction among participants. Working in a group setting, individuals share ideas, materials, and experiences, fostering a sense of community and belonging. The "greeting feature" of EmpowerBox, where boxes interact with each other through a handshake-like vibration, further encourages social engagement.

Finally, EmpowerBox serves as a testament to the power of social inclusivity. Participants discovered common interests and passions by creating and sharing their personalized EmpowerBoxes, leading to meaningful interactions and connections. The project advocates for a more inclusive and diverse world where the voices of individuals with intellectual disabilities are heard and valued.

This chapter expanded on Part III of this doctoral dissertation. The following chapter, Creativity with Artificial Intelligence, will continue the exploration of Creativity and Multisensory Integration by engaging people with intellectual disabilities in creative expression facilitated by AI.

9

Creativity with Artificial Intelligence

This doctoral dissertation's third and final chapter of Part III, focuses on Artificial Intelligence (AI). It is one of the chapters that provide content to answer RQ 1.3 (*How can we use technology to involve people with intellectual disabilities in creative and multisensory experiences?*) and to address RQ 3.3 (*How can generative artificial intelligence be used to stimulate the creativity of people with intellectual disabilities?*). This work emerges as a critical effort to integrate cutting-edge technology with creative expression, seeking to enhance the accessibility and engagement of people with intellectual disabilities. This effort stems from AI's significant ability to generate input and inspire the creation of new content. As we navigate the complex landscape of AI capabilities we must strike a balance between exploring AI's positive advantages and critically examining its limitations and ethical implications.

This chapter, conducted during my doctoral mobility at QUT in Australia, illustrates the potential of technology to enhance human creativity and emphasizes the importance of creating inclusive spaces where everyone can express themselves artistically. By using AI to combine original museum artworks with participants' drawings, Artistic Fusion offers an approach to empowering people with intellectual disabilities, welcoming them to make meaningful contributions to the cultural narrative.

Through these contributions, the research advances the field of HCI and advocates for a more inclusive and creative society.

9.1 Introduction

Artistic expression is a fundamental facet of human communication and emotional exploration. Engagement in artistic activities can support cognitive development, improve emotional well-being, and foster social connections [280]. For individuals with intellectual disabilities, however, conventional avenues of artistic creation and engagement with cultural spaces often present challenges that limit their opportunities for self-expression and participation. Innovative and inclusive approaches to artistic creation and cultural engagement are key to enabling meaningful participation.

Artificial Intelligence (AI) offers promising support and opportunities in the domain of artistic expression. AI technologies have rapidly advanced, showcasing their capability to generate diverse and intricate forms of artwork. In particular, generative AI can create new and innovative content by extracting and learning patterns from existing data. Algorithms such as GPT-4 [215] or Stable Diffusion [240] can produce diverse outputs such as images, text, or music that are novel and creative [203]. Generative AI also has the potential to make web accessibility more personalized for people with disabilities by adapting content to the preferences and needs of individuals [2].

Leveraging recent advancements in Generative AI, we introduce an inclusive approach to creative expressivity that we name "Artistic Fusion". This approach combines original museum artwork with drawings contributed by participants with intellectual disabilities, offering a tool for engaging meaningfully with artwork through personal creative inputs to merge with established artistic pieces. The fusion of artistic styles not only serves as a means of connecting distinct artistic techniques but also has the capacity to empower individuals with intellectual disabilities. This empowerment is achieved through people's active participation in the artistic process, by supporting self-expression in the informal learning process; they contribute to the creation of a novel artistic object while keeping track of modifications made to the original contribution.

People with intellectual disabilities have the entitlement to participate in everyday activities and enjoy the benefits of cultural heritage. Museums and cultural spaces have long been symbols of shared human experiences and narratives, and it is imperative that they are welcoming and representative of diverse populations. By incorporating the Artistic Fusion approach, these spaces can transform into platforms that not only display art but also encourage its co-creation by individuals who have traditionally been underrepresented. Further, to ensure the integrity and authenticity of AI-augmented creative processes, we propose a framework that includes human curation and moderation. This framework outlines specific roles for curators to oversee the AI's output, ensuring that the final artwork aligns with the creative intentions of the participants while remaining culturally sensitive and inclusive.

In this chapter, we are exploring the potential of AI-generated artwork to facilitate creative expression for individuals with intellectual disabilities, empowering individuals with intellectual disabilities to engage with informal learning through artistic creation. This endeavor aligns with the broader societal goal of fostering inclusivity, enabling active participation, and dismantling barriers that hinder creative engagement for all individuals. We implemented Artistic Fusion as an activity within a series of workshops where people with intellectual disabilities engaged with a museum through various technologies. We contribute some initial observations and a discussion on how Artistic Fusion can support creative expression, inclusion, empowerment, enjoyment, and engagement for people with intellectual disabilities through an enjoyable activity.

We organize this chapter as follows: In Section 9.2 we explain the methodology we used, including details about our participants, the procedure we used, and our data and ethical considerations. Section 9.3 brings our initial findings about the influence on creative expression, inclusivity, empowerment, enjoyment, and engagement with the Artistic Fusion process. Section 9.4 brings a discussion about AI. Section 9.5 concludes this chapter. Lastly, a comprehensive exploration of technologies for the inclusion of people with intellectual disabilities, AI and accessibility, and augmenting abilities with AI was already introduced in Section 2.10.

9.2 Methodology

9.2.1 Participants

All individuals included in our study are considered research participants according to their identification by the supporting organization and the National Disability Insurance Scheme (NDIS) as individuals with an intellectual disability. They receive assistance within urban communities located in Australia, and they possess Australian citizenship. They take part in group settings, where a variety of activities are provided to facilitate their developmental goals. This support is offered both within a day center and in the broader community. We refrained from inquiring about medical diagnoses, as such inquiries are considered irrelevant to the scope of our research. Furthermore, the conducting of IQ tests was not included in our research methodology, since we considered them to be irrelevant to the nature of our study. We had five participants in total during the two weeks of activities. P27 is a man in his late 40s, P28 is also a man in his late 40s, P29 is a woman in her 30s, and P30 and P31 are men in their early 20s.

9.2.2 Research Design and Procedure

This study builds on observations and collective reflections of a series of three workshops with a group of five adults with intellectual disabilities and two support workers. The workshops were offered as an activity about art and technology at the Queensland University of Technology (QUT) for three sessions of two hours in three consecutive weeks.

During the first workshop with AI – known as AW2 in this doctoral dissertation, participants were introduced to the museum artworks using ACCESS+ [246, 275]. Subsequently, they were taken on a museum visit to the QUT Art Museum, where they had the opportunity to engage with original artworks by the Australian artist Ethel Spowers (1890–1947). During the museum visit, participants were encouraged to interact with the researchers, a cultural mediator, and a social robot to establish a deeper connection with the artworks. Following their museum visit, participants were encouraged to express what they found most appealing about the museum experience through drawings. These drawings were intended to capture their personal interpretations and emotions related to the artworks they encountered. The initial set of drawings was subsequently used as a foundation to create the initial examples of Artistic Fusion.

The step-by-step Artistic Fusion process was as follows: participants' drawings were scanned and uploaded to the Midjourney platform, where a set of parameters pre-determined by the research team guided the fusion of images. While Midjourney provided a robust starting point, fine-tuning was occasionally required to better align the AI's output with the participants' vision.

During the second workshop with AI – known as AW3 in this doctoral dissertation, participants were presented with the outcomes of their individual drawings merged with the original museum artworks. The first author provided an explanation of the "Artistic Fusion" concept and guided participants on how to reinterpret their own creations in light of this fusion. Participants were then prompted to create new artistic expressions inspired by the original artworks, their initial drawings, and the AI-generated Artistic Fusion images.

After that, with their new drawings scanned and available on the computer, a researcher facilitated the Artistic Fusion process. Everyone could see the ongoing process on a screen projected in the middle of the workshop room. The support workers helped participants whenever needed. Participants were given the opportunity to select both their own artwork and their preferred available original museum artwork, Artwork 1 (Fig. 9.1a) or Artwork 2 (Fig. 9.1b). This selection process provided insights into their preferences and creative inclinations. Following the processing stage, participants could select one image between four

AI-generated images to upscale, generating an increased size and more detailed version of their choice.

The research employed a mixed-methods approach to gather detailed feedback from participants, focusing on qualitative over quantitative data. This approach entailed the qualitative analysis of participants' feedback, including narrative responses, emotional reactions, and the extent of assistance and collaboration with the facilitators. Quantitative data was collected in instances such as when participants selected an image to upscale (from image one to four) or when identifying their preferred AI outcome. The observations were made by a team of researchers who also captured video data during the workshops (authors 1, 2, and 3). The collective reflections were held together with the workshop organizers (authors 1, 2, 3, and three students) and the researchers at the end of each workshop for a duration of around 45 minutes and were audio recorded. Author 4 was overseas helping us to create the research and write this study. In this chapter, we focus on observations and reflections that relate to the Artistic Fusion activity. We analyzed participants' reactions and preferences in order to answer our research questions.

(a) Artwork 1 (A1): School is Out (1936) (b) Artwork 2 (A2): Balloons (c. 1920)

Figure 9.1. Artworks by the Australian artist Ethel Spowers (1890–1947).

9.2.3 Data and Ethical Considerations

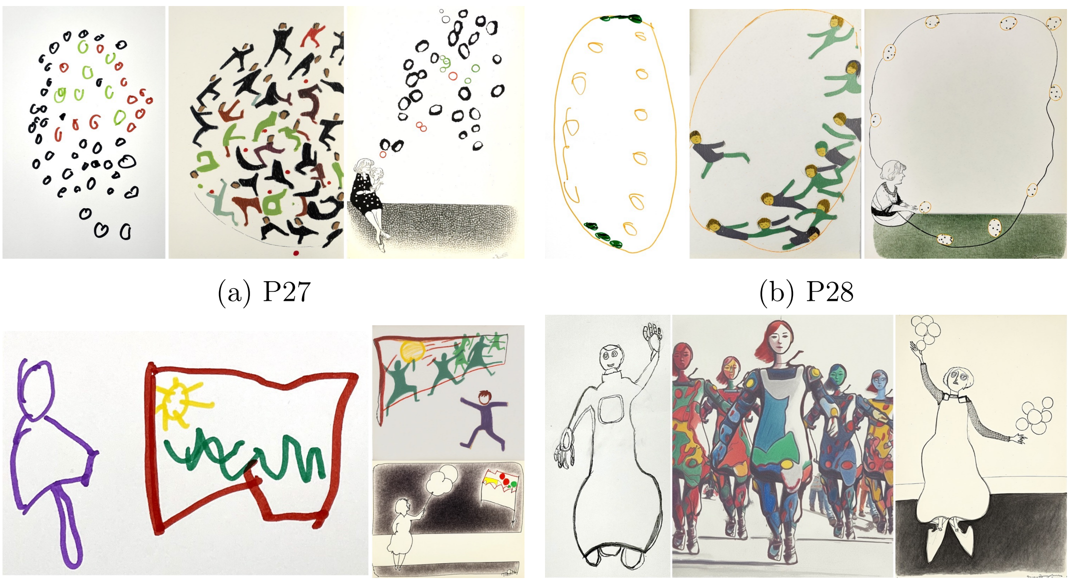
Informed consent was secured from participants or their guardians prior to participation. Privacy and confidentiality were maintained throughout, with participants empowered to decline engagement in artwork creation or workshops. We provided all the possible measures to minimize potential discomfort or harm. Participants' drawings were scanned and we kept them safe from identification, without any private information stored. We recorded a video of the workshop for further analysis. The video was saved in the university server and was only accessed for analyzing participants' reactions or details related to the research procedure. No data related to participants' names or sensitive personal information was stored. For the AI-generated images, we used Midjourney, uploading images that had no identification of our participants. The museum has the copyrights to edit and distribute the original artworks, making it possible for our team to use them with Artistic Fusion and include them in the chapter because of this collaboration. The ethics approval for this study was granted by the QUT ethics committee, as part of protocol number [2000000213]. The protocol supports voluntary and informed participation with easy-read consent forms, verbal reminders to participants while they take part in the study, and attention to body language for signs of wishing to quit the study.

9.3 Initial Findings

Participants engaged with museum artworks through the ACCESS+ app, providing a preliminary introduction to the artistic content. This interaction was integral in preparing participants for their museum visit to the QUT Art Museum. The importance of familiarising participants with the museum's offerings prior to their physical visit was evident. This preparation facilitated a smoother engagement process during their museum visit, enhancing their overall experience. During the museum visit, participants interacted with original artworks by Ethel Spowers, facilitated by researchers, a cultural mediator, and a social robot. These facilitators played a role in guiding discussions, providing historical context, and fostering conversations around the artworks. However, their presence was complementary rather than directive. Participants retained the independence to form their interpretations, ask questions, and engage with the experience. This engagement allowed participants to establish deeper connections with the artworks, facilitating personal interpretations and emotional connections, with expressions of awe and quiet contemplation. The experience supported the participants' ability to express their feelings and thoughts visually through Artistic Fusion.

9.3.1 Influence on Creative Expression

The initial Artistic Fusion process marked a transformative juncture where participants' creative expressions through their drawings took on a new dimension. Their drawings were merged with the original museum artworks available in Fig. 9.1. The images generated are available in Fig. 9.2. Four participants contributed with drawings (P27, P28, P29, and P30), while one participant (P31) was absent, joining the following workshop. This process ignited new creative perspectives, leading participants to perceive their creations differently.



(a) P27 (b) P28

(c) P29 (d) P30

Figure 9.2. Images generated after the museum visit. On each subfigure, clockwise, the transformation from participants' original drawings to AI-generated fusion with Artwork 1 and Artwork 2.

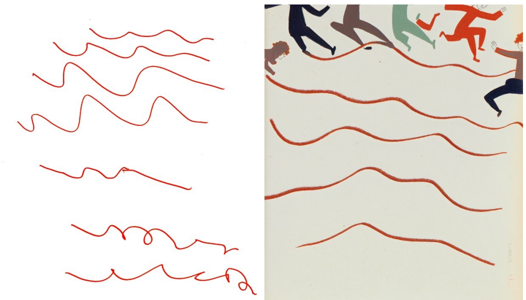
Upon receiving their Artistic Fusion-created artworks at the workshop's outset, participants displayed a mix of emotions, primarily excitement and joy, witnessing their creations fused with AI. P27 said, "*It's beautiful*". When questioned about their preference between their original creations and the AI-generated versions, all participants favored the latter. One participant (P30) showed his favorite AI-generated image, the central picture available in Fig. 9.2d. He highlighted the colors and the number of robots in the generated image.

The introduction of the Artistic Fusion process had an impact on the participants' subsequent creative expression. Once they realized that their drawings could be merged with existing artworks through AI, their approach to creation underwent a noticeable transformation, adding more colors or focusing on different aspects of the original artwork. The prospect of collaboration with AI and established artworks seemed to broaden their creative horizons. Participants proudly showcased their fused creations, often identifying elements from their original drawings that had been transformed through the fusion process. This sense of ownership over the results was not diminished by the AI's involvement; instead, it seemed to solidify their pride in their contributions to the collaborative pieces.

9.3.2 Inclusivity and Empowerment

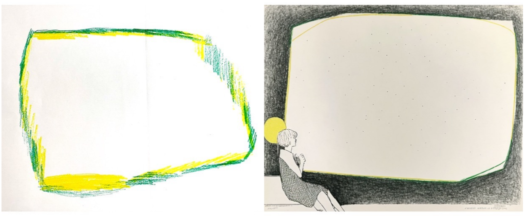
Participants' journey continued through a creative empowerment workshop. Here, they engaged in the Artistic Fusion process themselves, selecting their own artwork and their preferred original museum artwork. This empowerment step allowed participants to actively influence the fusion process, granting them a greater sense of agency and ownership over their artistic endeavors. Some of the fused drawings are available in Fig. 9.3. All participants contributed with drawings. We are displaying four examples, two originating from Artwork 1, and the other two from Artwork 2.

During the workshop, participants exhibited a high level of agency and engagement in operating the application. While some participants required occasional prompting and support to navigate through the Artistic Fusion process, the overall experience showcased a high degree of inclusivity. The participants' ability to independently select their preferred original artwork and collaboratively choose their drawings for fusion highlighted their active involvement in the creative journey. A strong collaboration developed between participants, researchers, a social robot, a cultural mediator, and support workers to create an inclusive and dynamic artistic environment, fostering a sense of community and shared accomplishment. The support workers played a crucial role in providing assistance and guidance throughout the process. Their presence facilitated a smooth workflow and ensured that participants felt comfortable and empowered to express themselves fully. Support workers limited their input to prompting participants to choose their artworks and at no point, made suggestions of what they might prefer.



(a) P27's drawing and the fusion with A1

(b) P31's drawing and the fusion with A1



(c) P28's drawing and the fusion with A2

(d) P30's drawing and the fusion with A2

Figure 9.3. Images generated during the workshop. On each subfigure, the transformation from participants' original drawings (left) to AI-generated fusion with the original Artwork.

The participants' influence over the outputs was prominently demonstrated during the workshop. The choices made by participants were diverse and indicative of their distinct artistic preferences. Notably, participants often explored multiple rounds of fusion, opting for different combinations to see how their drawings interacted with the original museum artwork. This experimentation suggested a high level of control and ownership over the creative process. While some participants did occasionally choose the first proposed fusion, many actively sought out new combinations, showcasing their autonomy in shaping the final artistic outcomes. This dynamic decision-making process underscored the participants' agency and control over the creative collaboration, further emphasizing the success of the inclusive and empowering workshop environment.

9.3.3 Enjoyment and Engagement

The analysis of participant reactions and preferences revealed several interesting insights. A noteworthy observation was the evident delight and curiosity displayed by many participants during the process of merging their drawings with the original artworks. Participants value the co-creation capabilities of generative AI as they can feel ownership over the creations and learn from the process [125]. Additionally, the engagement with the AI-generated Artistic Fusion images added a new dimension to their creative experience. Some participants discussed how the AI-generated images provided unique combinations that they hadn't considered before, which sparked creativity boosting.

During the workshop, participants shared their creations with us, underscoring the impact of Artistic Fusion. P28 described his contribution - designing the tablet interface of the social robot. He was previously interacting with the tablet to play a game about the museum artworks, and this inspired his new drawing. The final fusion result (depicted in Fig. 9.3c) incorporated his artwork as a framing element for the original masterpiece. This integration seamlessly aligned with the tablet's purpose of showcasing artwork. As a result, P28 found himself captivated and content with the result. As participants explored the fusions, they were presented with the option to experiment with the remaining different artwork. Among them, P31, a minimally verbal newcomer to the workshop, became acquainted with the artworks and effectively conveyed his thoughts through gestures. These gestures included a confirming thumbs up or pointing, demonstrating the accessibility and engagement of the experience.

In the pursuit of discerning individual inclinations, we inquired the participants regarding their preferences between their own creations and those generated by AI. P27 and P29 expressed a preference for their own drawings. Participant 3 specifically emphasized, "I like mine because it's human". On the other hand, P30 and P31 favored the outcome of Artistic Fusion. P28 displayed uncertainty, oscillating between preferences before ultimately concluding a preference for both. This variety in preferences highlighted the diverse range of attitudes participants had toward the co-creative process with AI.

9.4 Discussion

AI techniques possess the characteristics of creativity as they can exhibit novelty, value, and unexpectedness within a given application context. As a result, the rise of generative AI approaches holds significant promise in supporting creative endeavors in diverse manners [203]. We discuss how Artistic Fusion can contribute to participating approaches for co-designers, as well as its current limitations and risks.

Due to this vast potential to amplify human creativity, it is essential to co-design generative AI systems with various stakeholders to understand their needs and requirements [125]. Initiating the process of selecting both the initial artwork and the original museum pieces enabled researchers to reveal significant patterns in participants' aesthetic preferences and artistic inclinations. This exploration allowed researchers to understand how individuals with intellectual disabilities engage with art, discerning the particular aspects of the original artworks that held a strong connection for them. This investigation not only added depth to the collaborative process but also set the foundation for a more comprehensive, inclusive, and impactful artistic involvement within this community, recognizing divergent creative modes [159].

While Artistic Fusion is intriguing, it is important to recognize that there are potential drawbacks and biases associated with the use of AI in this context. The blending of AI-generated artwork with contributions from individuals with intellectual disabilities raises questions about the authenticity and originality of the final artwork [330]. While the goal is to empower individuals with intellectual disabilities, there is a potential risk of inadvertently reinforcing a power dynamic where the AI-generated elements overshadow the contributions of the participants. We attempted to mitigate this challenge by providing alternatives to our participants, allowing them to continue editing the AI creation to fulfill their artistic needs. However, further investigations would help address these questions more in-depth.

In Artistic Fusion, the AI's interpretation of cultural elements might not be accurate or sensitive, potentially leading to misrepresentations or cultural insensitivity within the collaborative artwork. Participants might question whether the artwork truly represents their emotions and experiences or if it is an externally biased interpretation, in a similar way to what a member of their support network might impose. A true collaborative tool would be able to listen in the way that collaborative artists do to capture the intent and emotions, beyond the aesthetic features of the combination. That being said, Artistic Fusion is a tool that participants can choose to use as they see fit, as they may continue their interpretations independently.

To address the potential biases and concerns identified, we propose a framework for human-AI collaboration that includes the role of human curators and moderators. These individuals would not only oversee the AI's output but would also bring an understanding of cultural contexts and sensitivities to the process. They would work to identify and correct any misrepresentation or biases in the AI-generated content, drawing on diverse perspectives and inclusive practices. The correction process would involve iterative cycles of review and adjustment, where the participants' feedback is continuously sought to ensure that the final artwork aligns with their intentions and is culturally sensitive.

Finally, AI models can inadvertently under-represent certain groups, as they learn from existing data and replicate biases present in society. This is likely to lead to an uneven representation of artistic styles or cultural backgrounds in the final fusion. Introducing human curators or moderators who review and refine the AI-generated elements can help correct bias and ensure that the final artwork respects the intentions and emotions of the participants. Continuing the user-centered design approach and feedback cycle highlighted in this doctoral dissertation is crucial. Regular engagement with participants and iterative adjustments based on their input can help address biases as they emerge.

9.5 Conclusions

This chapter has explored the transformative potential of AI-generated artwork as a means to promote creative expression and inclusivity among individuals with intellectual disabilities. Through the lens of the "Artistic Fusion" approach, which combines original museum artworks with participants' drawings, this study has highlighted the power of collaboration between human creativity and AI capabilities.

The Artistic Fusion concept bridged diverse artistic styles and provided participants with a platform to contribute to the ever-evolving landscape of art creation. The collaborative workshop sessions revealed the potency of participant agency in shaping AI-generated enhancements, challenging traditional notions of passive engagement. The research aligns with the aspiration of fostering inclusivity and dismantling barriers to creative engagement.

The journey uncovered emotions like excitement, joy, and curiosity as participants saw their creations fuse with AI-generated artwork. AI as a collaborative tool expanded creative horizons, encouraging experimentation. Interaction with AI-generated collaborative artwork facilitated personal interpretations and emotional bonds with the art, enabling expression.

This study concluded the groundwork for exploring RQ 1.3, which will be discussed in Chapter 10, and addressed RQ 3.3: "How can generative artificial intelligence be used to stimulate the creativity of people with intellectual disabilities?". The response is summarized in several main points:

- **Artistic Fusion and Empowerment**: Artistic Fusion involves blending original museum artworks with participants' drawings through AI, creating a new artistic expression. It empowers individuals by giving them a tangible role in the creation process, enhancing their sense of contribution and ownership. This method diversifies artistic expression and strengthens individuals' confidence in their creative capabilities.

- **Customized AI-generated Artwork**: Utilizing generative AI to create personalized artwork offers a unique way to engage the participants in art-making. The customization ensures that each piece of art resonates with the creator, making the creative process more meaningful and stimulating. It encourages participants to think expansively about the possibilities of art.

- **Framework for Human-AI Collaboration**: This framework requires the presence of dedicated curators and moderators who actively guide the AI's outputs to ensure they resonate with the participants' visions while maintaining cultural relevance and emotional sensitivity. These professionals are tasked with identifying any potential misrepresentations or biases in AI-generated content. By drawing on diverse perspectives and adopting inclusive practices, they ensure that the collaboration results in outputs that are both innovative and respectful of varied cultural contexts.

- **Iterative Creation and Reflection**: Engaging participants in an iterative creation, reflection, and recreation process based on AI-augmented artwork encourages continuous learning and adaptation. This cycle allows individuals to reflect on how their ideas have been transformed by AI, inspiring them to refine their creative vision further. Such an approach fosters a dynamic creative process where feedback and adaptation play critical roles, progressively enabling participants to develop their artistic skills.

Finally, combining AI-generated elements with participants' work raises concerns about authenticity and originality. Cultural sensitivity and bias require careful consideration. Collaborative artwork might inadvertently perpetuate misrepresentations, raising concerns about capturing emotions without introducing biases. Inherent biases in AI models could lead to uneven representation of artistic styles or cultural backgrounds. Meticulous curation and human moderation are crucial to mitigate biases and ensure respectful representation. In navigating AI, creativity, and inclusivity, emphasizing benefits while addressing challenges is essential. The relationship between human imagination and AI innovation promises an artistic landscape that celebrates human diversity and pushes creative boundaries forward.

This chapter concluded Part III of this doctoral dissertation. The following chapter, Chapter 10, will provide a discussion of the content from all the first three parts, as part of the Part IV, Discussion and Conclusions.

Part IV

Discussion and Conclusions

10

Discussion

10.1 Inclusive Design for Intellectual Disabilities

This section discusses RQ1: "How can we design technologies with and for people with intellectual disabilities?" by addressing RQ 1.1 and, in the following sections, the RQ 1.2 (Section 10.1.1) and RQ 1.3 (Section 10.1.2). These questions were left pending as they required an assessment of the overall findings from the study. Also, this chapter reports overall reflections, lessons learned, and considerations.

10.1.1 Involving Participants in Evaluating Digital and Interactive Prototypes

Involving people with intellectual disabilities in evaluating digital and interactive prototypes for museum visits demands a nuanced and comprehensive approach that intertwines several critical aspects of participatory design and technology integration. At the heart of this endeavor is creating an inclusive environment where accessible communication methods, such as simplified language and visual aids, ensure that individuals with intellectual disabilities can provide meaningful feedback.

The digital and interactive technologies presented in this doctoral dissertation have played a pivotal role in shifting participants from passive observers to active contributors. The iterative testing and co-design process were fundamental, where participant feedback led to continuous adjustments, ensuring that the developed solutions resonated with their needs and preferences. Social robots, accessible applications, and augmented reality have been explored and tailored to enhance the cultural experience of people with intellectual disabilities. This section delves into RQ 1.2: "How can we use participatory evaluation to improve the design of digital and interactive prototypes for museum visits with people with intellectual disabilities?".

Augmented reality (AR) offers transformative opportunities to enrich museum visits for individuals with intellectual disabilities. In the design of AIMusem – the AR prototypes – introduced in Chapter 4, participatory evaluation guides the adaptation of technology to meet the specific needs and preferences of the target audience. The evaluation process for the AIMuseum application involved several key methodologies to accommodate diverse participant abilities and preferences. Traditional feedback mechanisms were adapted for accessibility, incorporating visual aids, simplified language, and direct interaction with prototypes to gather comprehensive feedback. Hands-on activities enabled direct interaction with AR elements, facilitating an understanding of user preferences for 3D content, realism, and audio feedback. Scaffolding techniques were employed to gradually introduce participants to the AR application, ensuring effective engagement and contribution from all. Further, the participatory evaluation revealed a strong preference among participants for AR solutions over other alternatives, highlighting the approach's effectiveness in garnering user insights and preferences.

Accessible applications empower individuals with intellectual disabilities to customize their museum experiences according to their preferences and needs. The ACCESS+ application introduced in Chapter 5, initially deployed to be used in Italy and later adapted for Australia, demonstrates the potential of inclusive design in improving UX for a broader and international audience of people with intellectual disabilities. Through participatory design processes, such as brainstorming sessions, focus groups, scaffolding, and hands-on activities, the co-design of ACCESS+ prioritized inclusive features such as customizable UI elements and text-to-speech. Utilizing AAC pictograms and easy-to-read texts further exemplified the application's commitment to accessibility. Heuristic evaluations and feedback from special education experts further refined the application's usability and accessibility, demonstrating the effectiveness of participatory evaluation in improving digital prototypes for museum visits. By involving end-users throughout the design process, researchers can ensure that the resulting applications are technically robust and genuinely meet the diverse needs of individuals with intellectual disabilities. The engagement with ACCESS+ facilitated a deep understanding of the participants' experiences, preferences, and challenges, particularly in navigating digital interfaces. It also highlighted the necessity of adapting evaluation methods to be accessible, incorporating feedback mechanisms catering to non-verbal individuals, those with low vision, or those with varying literacy levels. The positive feedback from participants and their overall choice of high-tech solutions over low-tech ones indicated a strong preference for using such accessible applications to engage with museum content, suggesting that these solutions can significantly enhance museum experiences for people with intellectual disabilities.

Integrating social robots into museum visits offered unique opportunities for engagement and interaction for our participants with intellectual disabilities. In the study introduced in Chapter 6, participatory workshops played a central role in tailoring the robot's interactions to the audience's needs. Participants interacted with the robot through activities like dance performances, action selection, playing games, and engaging in quiz games about museum artworks. These activities were designed to familiarize participants with the museum content and the robot, fostering a comfortable and engaging informal learning environment. The workshops emphasized the importance of diverse forms of interaction, facilitated through the robot's use of voice, text, and gestures, which helped to break down barriers to access and engagement with museum content. Moreover, the study's methodology was sensitive to the participants' varied communication styles and preferences. By offering multiple modes of interaction with the robot and the museum content, the study catered to individual needs, ensuring that participants could engage in ways that were most meaningful to them. Doing these steps, the study increased accessibility and engagement and fostered social interactions among participants, enhancing the overall museum experience.

Following the Affordance Theory [302], the exploration of digital and interactive technologies suggests an underlying consideration of the affordances these technologies provide, highlighting the relationship between the physical characteristics of technology and how they can be perceived and used by participants. By leveraging affordances, designers can ensure that users with intellectual disabilities can readily comprehend and engage with the technologies presented to them. Incorporating affordance theory into participatory evaluation processes can facilitate the identification of design elements that may enhance usability and accessibility for individuals with intellectual disabilities, leading to more inclusive and effective technological solutions for museum experiences.

Managing user expectations is also crucial, especially among participants with advanced technological experience. Museums must provide realistic portrayals of what their technologies can offer, aligning them with actual experiences to prevent any disparity between expectations and reality, as we saw with P10 and P30 during Italian and Australian sessions. Additionally, the design and presentation of digital and interactive technologies require careful consideration to ensure they meet user expectations regarding functionality and interaction capabilities.

Participatory evaluation is vital in designing and developing technologies to improve museum experiences for individuals with intellectual disabilities. Whether through social robots, accessible applications, or augmented reality, the integration of participatory evaluation ensures that these technologies are inclusive, engaging, and tailored to the audience's diverse needs. Continuing collaboration and iterative refinement through participatory evaluation will be essential in advancing the field of inclusive technology design for museum visits.

10.1.2 Involving Participants in Creative and Multisensory Experiences

Leveraging technology to involve individuals with intellectual disabilities in creative and multisensory experiences is essential for fostering inclusivity and engagement. By embracing a Participatory Design approach, these initiatives ensure that technology solutions are not only accessible but also resonate with the unique needs and preferences of people with intellectual disabilities. EmpowerBox and the Multisensory Diorama highlight the critical role of sensory engagement in creating interactive experiences. Integrating various electronic components, these projects offer multisensory stimulation that caters to different learning styles and sensory preferences, making cultural, educational, and creative content more accessible and engaging.

Further, empowering individuals through creative expression is essential to EmpowerBox and Artistic Fusion. By combining tools with human creativity, Artistic Fusion offers new avenues for artistic exploration and personal expression. The study amplifies the voices of people with intellectual disabilities who are often marginalized and fosters a deeper connection with the broader cultural and artistic community. This section delves into RQ 1.3: "How can we use technology to involve people with intellectual disabilities in creative and multisensory experiences?".

Multisensory Diorama (MSD), introduced in Chapter 7, was designed to provide an immersive learning environment through tactile, auditory, and visual stimuli in a museum setting. The design of the MSD was informed by initial research and focus groups involving psychologists, educators, and individuals with intellectual disabilities. Participants were encouraged to explore the diorama freely at first. The researchers observed and took notes on how participants interacted with the diorama, focusing on their natural inclinations toward the multisensory elements. The MSD offered interactive storytelling and a gamified learning experience focused on the food chain to engage users. Participants could interact physically with the diorama elements, triggering sensory feedback that reinforced learning outcomes. This hands-on approach catered to different learning styles and preferences, promoting an inclusive educational experience. We acknowledged that some participants might require more support than others and used scaffolding to provide support.

The EmpowerBox project, introduced in Chapter 8, offers a dynamic approach to engaging individuals with intellectual disabilities in creative and multisensory experiences, leveraging technology and the principles of the maker movement. The methodology included the use of hands-on methods, sensory engagement, and personal storytelling, allowing participants to communicate their identities and preferences in a tangible and creative form. By integrating LEDs, fans, vibromotors, and tactile materials, EmpowerBox enhances nonverbal forms of expression and supports social interaction through shared activities and the "greeting feature". EmpowerBox demonstrates the potential of inclusive design to foster creativity, learning, collaboration, and community among individuals with intellectual disabilities, challenging conventional notions of communication and advocating for diverse forms of expression.

Integrating AI in creating multisensory and creative experiences for people with intellectual disabilities represents a transformative approach to inclusivity. As outlined in the doctoral dissertation's Chapter 9, this research focuses on generative AI algorithms to merge participants' artwork with original museum pieces, enabling a novel form of artistic expression. The methodology was carefully tailored to accommodate individuals with intellectual disabilities by allowing creative expression and providing supportive workshop environments. This facilitated a Participatory Design process, allowing for genuine creative expression and ensuring the artwork reflected the participants' intentions and emotions. By involving participants and moderators, the chapter proposed a structured framework for human-AI collaboration to ensure that the technological aspects of creativity were balanced with human insight, emphasizing the importance of cultural and emotional sensitivity. Finally, we used debriefings to discuss the workshop's outcome.

By enhancing accessibility and engagement, technology plays a pivotal role in promoting social inclusion and cultural participation. The act of creating something personal and functional, like EmpowerBox, empowers participants. It provides a sense of accomplishment and boosts self-esteem as individuals see their ideas and efforts materialize into a tangible product. This empowerment is critical for individuals with intellectual disabilities, promoting independence, confidence, and a positive self-image. The research presented in Part 8 opens up spaces where individuals with intellectual disabilities can contribute to and partake in the richness of cultural heritage and the arts, enriching not only their own lives but also the social fabric of the community. Through these technological endeavors, society moves closer to realizing a more inclusive and vibrant cultural landscape where diversity is recognized and celebrated.

10.2 Engagement with Digital and Interactive Technologies

Engaging people with intellectual disabilities with digital and interactive technologies, particularly with augmented reality, accessible applications, and social robots, reveals significant advancements in accessibility and the user experience. Each of these technologies uniquely enhances access to information and interaction, catering to the varied needs and preferences of individuals with intellectual disabilities. This section delves into RQ 2: "How do people with intellectual disabilities access and engage with digital and interactive technologies?" after discussing the RQ 2.1 (Section), RQ 2.2 (Section), and RQ 2.3 (Section).

Augmented Reality, exemplified by the AIMuseum application in Chapter 4, has significantly improved access to and engagement with museum content for individuals with intellectual disabilities. By integrating AR with QR codes, participants can interact with museum exhibits in a more dynamic and immersive manner, making educational content more accessible and engaging. The preference for audio feedback and 3D content within AR applications underscores the importance of auditory elements and interactive models in enriching the digital museum experience. Despite initial challenges, the ease of learning and using AR technology highlights its potential for educational and cultural applications. Moreover, AR's capacity to elicit a wide range of emotional responses underscores the need for personalized experiences catering to individual preferences, needs, and comfort levels, enhancing engagement and emotional connection with the content.

Accessible applications, such as the ACCESS+ application available in Chapter 5, are designed with customizable features like adjustable icon and text sizes, high contrast modes, and the inclusion of AAC pictograms, which significantly enhance content accessibility for individuals with intellectual disabilities. The design elements that support engagement, including easy-to-read text formats, text-to-speech functionalities, and emotional rating scales, allow users to interact with content in ways that suit their abilities and preferences, fostering a deeper connection with the material. The positive feedback from participants indicates a strong preference for using such applications, highlighting their effectiveness in overcoming traditional barriers faced in museum settings. Focusing on a broad range of UX considerations, such as intuitive UI, simple navigation, and clear instructions, is crucial for creating truly accessible and enjoyable applications.

Social robots presented in Chapter 6, like Pepper, which is equipped with an interactive tablet, offer an innovative way to make art and museum exhibits more accessible to individuals with intellectual disabilities. These robots facilitate understanding and appreciation of the content by presenting information in various modes, including voice, text, and gestures. The engagement levels of people with intellectual disabilities significantly increase with the introduction of social robots, as they provide interactive activities like quizzes and artwork information that encourage active participation and sustained interest. Human facilitators also played a crucial role in complementing Pepper's functionality. Furthermore, social robots foster social interactions among participants, enhancing the overall museum experience through shared interactions, guided tours, and conversations initiated by the robots.

The accessibility and engagement of people with intellectual disabilities with digital and interactive technologies are enhanced through AR, accessible applications, and SR. Participants understand, use, and benefit from each technology in a different way. When we provide alternatives, participants can choose between using one technology over another or not using any high-tech devices.

Each solution offers unique benefits that cater to the diverse needs and preferences of people with intellectual disabilities, providing more inclusive and enriching experiences. These advancements improve access to educational and cultural content and promote greater engagement, emotional connection, and social interaction, highlighting the importance of continued innovation and customization in technology design for accessibility.

10.3 Aiding Creativity and Multisensory Inclusion

In our quest to understand the intersection of technology and accessibility for individuals with intellectual disabilities, this section delves into RQ 3: "How can we leverage technologies to engage people with intellectual disabilities in creative expressions and multisensory experiences?". Through the lens of various case studies and projects, this section illustrates the power of technology in making creative expression and learning accessible and enjoyable for people with intellectual disabilities. Examining these initiatives uncovers the potential of technology to break barriers and provide rich, personalized experiences that cater to the unique needs of individuals with intellectual disabilities, thereby promoting a more inclusive society.

The MSD project, available in Chapter 7, employs diverse engagement methods, including tactile, auditory, and visual elements, to accommodate different sensory preferences and learning styles. Such a multisensory approach ensures that participants can engage in a way that is most effective for them, thereby enhancing accessibility. Additionally, adaptive interaction designs that allow for personalization and scaffolding ensure that every individual can interact independently with the content regardless of their ability level. Implementing feedback mechanisms further enriches the learning experience, making content more understandable and engaging. Moreover, integrating interactive games into educational tools makes learning more enjoyable and strengthens understanding and retention by providing hands-on experiences that cater to various learning needs. Emotional engagement, supported by these technologies, is essential for producing memorable and successful learning experiences.

EmpowerBox, introduced in Chapter 8, illustrates the impact of combining personalization, sensory engagement, and social interaction in fostering creative expression. By allowing users to customize their boxes with images, decorations, and electronic components, EmpowerBox offers a unique avenue for self-expression and identity exploration. Individuals tell their stories and express their identities through a tangible, creative form, making it a personal experience. Including multisensory elements such as LED lights, fans, vibromotors, and tactile materials enriches the sensory experience, supporting non-verbal forms of communication. This multisensory approach caters to the diverse sensory preferences and needs of individuals with intellectual disabilities, enabling them to communicate and express themselves in ways that are most meaningful to them. Furthermore, the process of creating EmpowerBox promotes social interaction and a sense of community among participants. The shared activities and the boxes' "greeting feature" encourage users to engage with one another, fostering social connections and enhancing the collective creative experience.

Artistic Fusion, explored in Chapter 9, blends original museum artworks with participants' drawings using AI, allowing individuals to see their ideas merge with original artworks, enhancing their sense of contribution and ownership. This strategy increases artistic expression and increases confidence in their creative ability. Implementing a structured framework for human-AI collaboration is critical, as it ensures that the technological contributions to the creative process are balanced with human insight and emotional and cultural sensitivities. Moreover, engaging participants in an iterative creation and reflection process allows for a dynamic evolution of creative ideas. The cycle of creation encouraged continuous learning, adaptation, and refinement of artistic visions.

These creative and multisensory integration projects showcased how technology can be harnessed to create environments that are accessible and empowering. The initiatives exemplify the potential of multisensory and interactive technologies to transform the creative landscape, making it a place where everyone, regardless of their abilities, can express themselves. By embracing these technologies, we take significant steps toward a more inclusive and understanding society where the barriers to creative expression and sensory experiences are continually being dismantled.

10.4 The Importance of Communication

Effective communication is a key component of the research highlighted in this doctoral dissertation. The communication strategies employed in this study are multifaceted, emphasizing reciprocal interaction between researchers and participants, and extending to involve a broad range of stakeholders, including educators, support workers, students, psychologists, and cultural mediators. This section delves into the dynamics of these communications, underscoring their significance in the co-design process and the development of inclusive technology.

The communication between researchers and participants is inherently bidirectional, fostering an environment where ideas and feedback flow freely in both directions. Researchers communicate with participants by presenting ideas, prototypes, and methods, in an accessible and engaging manner. This is achieved through the use of an inclusive approach and scaffolding techniques, which are tailored to meet the participant's needs and abilities. The aim is to inform and inspire participants to share their thoughts, preferences, and experiences.

Conversely, participants are encouraged to communicate with researchers, using their favorite means of communication and offering insights into their interactions with the technology. This feedback is invaluable, as it directly influences the iterative design process, ensuring that the final prototypes are well-suited to the users' needs and preferences. A continuous dialogue is maintained through workshops, interviews, and hands-on sessions with the prototypes. The emphasis on diverse communication strategies enables effective engagement for all participants, catering to various learning and interaction styles.

The study recognizes the essential role of various stakeholders – educators, support workers, students, psychologists, and cultural mediators – in enriching the research process and enhancing the museum and creative experience of individuals with intellectual disabilities. These stakeholders bring diverse perspectives and expertise to the table:

- **Educators and support workers** are instrumental in facilitating communication between researchers and participants, often acting as mediators who provide the necessary scaffolding and support. Their close contact with the participants allows them to offer insights into their abilities, preferences, and potential challenges, ensuring that the communication strategies are effectively adapted. However, it is important to distinguish the caregivers' perspectives from those of the individuals themselves to ensure that the final designs authentically represent the users' desires and aspirations [132], shifting power dynamics [93].

- **Psychologists** play a crucial role in analyzing the emotional, cognitive, and social processes of the participants, offering guidance on how to tailor communication strategies to accommodate various needs and enhance comfort during sessions. Their expertise ensures that the research methodologies are sensitive to the psychological well-being of the participants.

- **Cultural mediators**, on the other hand, contribute by building engaging narratives that help describe the content of museum items in a way that resonates with the participants. They ensure that the communication of complex concepts is accessible and meaningful, facilitating a deeper connection between the participants and the museum content.

Establishing a sense of familiarity and comfort is essential for effective communication. The research team builds relationships with the participants, ensuring they feel comfortable and valued throughout the process. This is achieved through consistent engagement, where researchers make an effort to understand the participants' perspectives and adapt their communication style accordingly. The environment in which communication occurs is also carefully considered, with sessions designed to be welcoming and inclusive. By creating a space where participants feel safe to express themselves, the research fosters an atmosphere of mutual respect and understanding, which is fundamental for productive collaboration.

The communication strategies outlined in this doctoral dissertation underscore the importance of reciprocal, inclusive, and sensitive interaction between researchers, participants, and stakeholders. By prioritizing clear, accessible, and empathetic communication, the study advances the field of HCI and accessibility, contributing to creating more inclusive and engaging cultural experiences for individuals with intellectual disabilities.

10.5 Contributions

This section highlights the contributions of this doctoral dissertation within the HCI field, including Table 10.1 with the summary of findings and implications for Participatory Design, and content structured across several key parts:

Part I, Methodological Frameworks and Design, provides valuable contributions to the field of HCI, particularly emphasizing the inclusion of people with intellectual disabilities. It highlights the novel application of improvisation in research methodologies, underscoring the importance of adaptability in engaging with vulnerable populations during challenging times such as the pandemic. Furthermore, the scaffolding study introduces an expanded interpretation of the scaffolding concept, originally conceptualized by Wood et al. [324], applying it to co-design technology with people with intellectual disabilities. Detailed case studies illustrate the empowering effect of scaffolding in co-design sessions, offering a set of steps that guide towards a more inclusive co-design process. These contributions collectively advocate for a participant-centered, ethical approach to design and research in HCI, ensuring that technology development is accessible and reflects the needs of those with intellectual disabilities.

Part II, Digital and Interactive Technologies, significantly enhances our understanding and application of technology for inclusive and accessible learning experiences. AR uncovers user preferences among individuals with intellectual disabilities, emphasizing the need for audio feedback, realism, and interactive design to support independent learning. AR's potential to make museum visits more inclusive and interactive through participatory design underlines the crucial role of user involvement in developing empowering technological solutions. The chapter on Accessible Applications advances HCI by exploring how applications can be co-designed with individuals with intellectual disabilities. It highlights their preferences and the design iterations and stresses the importance of inclusive applications that foster independence and participation, incorporating insights from diverse stakeholders. Lastly, the section on Social Robots focuses on the role of social robots in museum settings, offering empirical insights into their engagement capabilities. It delves into the design considerations and challenges of creating social robots for public use while also addressing the ethical implications of their deployment in educational and cultural contexts. Together,

Table 10.1. Summary of Findings and Implications for Participatory Design

Research Question	**Key Findings**	**Implications for PD**
RQ 1	Adaptation of design methods, emphasis on co-design and scaffolding strategies, importance of improvisation and alternative communication, and involvement of caregivers.	Provides a set of adapted PD strategies for inclusivity.
RQ 2.1	AR enhances museum engagement, preference for audio/3D content, learning and usability insights, and personalized emotional engagement.	AR can be effectively integrated into PD for museum contexts.
RQ 2.2	Customizable interface, multimodal communication, intuitive UX, emotional engagement, user-centric development, impact on accessibility barriers.	PD must integrate customizable and multimodal features to meet diverse needs, involving users in design and iterative feedback processes.
RQ 2.3	Social robots improve accessibility and engagement, foster social interactions.	Social robots can be a medium for PD activities in educational settings.
RQ 3.1	Diverse engagement methods in a multisensory diorama, adaptive interaction design, educational engagement through feedback, interactive games, and emotional engagement.	Multisensory approaches enrich the PD process by accommodating different learning styles.
RQ 3.2	EmpowerBox's customization allows personal expression and communication, and encourages social interaction.	Personalized technology enhances creative expression in PD.
RQ 3.3	AI empowers artistic fusion, customized AI art, human-AI collaboration framework, iterative creation, and reflection process.	AI facilitates creative PD processes and outcomes.

these contributions highlight the transformative potential of digital and interactive technologies in creating more inclusive, engaging, and accessible learning environments.

Part III, Creativity and Multisensory Integration, significantly advances HCI through innovative concepts that foster inclusivity and creativity. The MSD represents a significant advancement in making learning experiences more immersive and accessible for individuals with intellectual disabilities. By integrating haptic, audio, and visual feedback, the MSD caters to diverse sensory preferences, thereby enhancing museum accessibility and promoting educational engagement through interactive games and feedback mechanisms. Further, the conception, design, and evaluation of the EmpowerBox approach demonstrates how a multisensory box can foster creativity, communication, and social interaction among people with intellectual disabilities and provide the broader societal benefits of promoting inclusive and creative collaboration. Moreover, the exploration of AI in supporting creative expression among individuals with intellectual disabilities highlights the transformative potential of technology. It suggests a framework for human-AI collaboration that respects empowerment and inclusivity, offering valuable insights into the ethical and practical challenges of integrating AI into artistic processes. These contributions underscore the importance of adaptive design and personalized technologies in creating accessible and engaging learning and creative environments for all abilities.

This doctoral dissertation significantly advances HCI by introducing new methods, promoting inclusivity, integrating digital tech, and setting the foundation for future research. It covers from theory to practice and ethics, highlighting HCI's evolving nature. The next section will examine the research's constraints, lessons learned, and future possibilities, emphasizing continuous improvement and innovation in HCI.

10.6 Limitations and Opportunities

This doctoral dissertation has explored various innovative approaches to enhancing the museum experience for individuals with intellectual disabilities through augmented reality, accessible applications, social robots, multisensory dioramas, multisensory self-representation boxes, and artificial intelligence. While each chapter presents significant findings and contributes valuable insights into the field, it is essential to acknowledge the limitations encountered during the research.

The implementation of augmented reality in museums faced contextual limitations. The absence of a dedicated room for assessments and the unfamiliarity of museums for a few participants affected the study outcomes. The varying literacy levels among participants influenced their interaction with labels and their preference for accessible texts. Additionally, participants' familiarity with technology was crucial to their individual experiences. These limitations suggest the need for adaptable and flexible augmented reality solutions that can accommodate diverse visitor backgrounds and literacy levels.

The study on accessible applications presented in Chapter 5 was limited by its single-site focus on a natural science museum and the participants' specific interest in museum content, which may have influenced the positive feedback. The research's applicability is further broadened by incorporating ACCESS+ during Australian workshops; however, an iteration session was not planned to be conducted there. The diverse needs of participants highlight the challenge of developing universally effective solutions.

Integrating social robots into museums highlighted limitations related to technological capabilities, design considerations, and the absence of a conversational agent. The reliance on human facilitators to complement the robots' functions underscores the need for advanced robot capabilities and strategic implementation. Addressing these limitations requires ongoing technological development and a multidisciplinary approach to utilize social robots in museum settings effectively.

The multisensory diorama study was impacted by environmental noise in the museum, which interfered with the audio feedback experience. This limitation underscores the importance of considering the museum's ambient environment in designing and implementing multisensory experiences.

Focusing on short-term outcomes and immediate participant experiences, the EmpowerBox study encountered initial technical challenges and highlighted the importance of accessibility in electronic components and workshops. Ethical considerations and the potential for bias in interpreting participant responses necessitate ongoing ethical reviews and co-design of research protocols with participants.

The use of AI in Artistic Fusion presents potential biases and challenges related to the authenticity and originality of the artwork. Concerns regarding cultural sensitivity and accurately representing participants' emotions and experiences through AI-generated elements highlight the need for further investigation.

This dissertation's exploration into accessible museum experiences through various technological interventions has revealed significant achievements and insights. Still, the limitations identified across the studies highlight the complexity of creating universally accessible and effective solutions. These challenges provide valuable directions for future research, emphasizing the need for continued innovation, ethical considerations, and a deeper understanding of the diverse needs of individuals with intellectual disabilities.

10.7 Future Directions

The research presented in this dissertation has laid a foundational framework for enhancing museum experiences for individuals with intellectual disabilities through various technological interventions. While significant strides have been made, future research still has considerable potential to build upon the findings and address the limitations identified in the preceding chapters. This chapter outlines the future directions for each thematic area explored within the dissertation, highlighting the potential for innovation and expanding knowledge in the field.

Future works will explore the integration of gamification with AR technology to enrich museum experiences further. By incorporating game design elements into AR applications, we aim to actively motivate participants to discover new content, making museum visits more engaging and educational. This approach capitalizes on the interactive capabilities of AR and aligns with the preferences of a diverse audience, potentially enhancing learning outcomes and visitor satisfaction.

To improve the usability and accessibility of museum applications, additional involvement of participants in co-design sessions is essential. Future investigations will focus on simplifying and customizing the user interface (UI) by implementing a block-based design approach, moving away from traditional menu bars. This initiative aims to make applications more intuitive and user-friendly for individuals with intellectual disabilities, facilitating easier navigation and interaction with museum content.

Future research in social robots will delve into integrating familiar and innovative technologies, tailoring them to the diverse needs and preferences of museum visitors. We aim to explore the relationship between participant backgrounds, engagement levels, and expectations towards technology. Investigating long-term engagement patterns and the impact of repeated interactions with social robots will offer insights into designing more inclusive and effective educational and recreational experiences.

Evaluating new multisensory feedback mechanisms and increasing speakers' volume is essential to enhancing the multisensory diorama's experience. Future work will focus on optimizing the auditory component of MSDs to ensure that the feedback is clear and immersive, even in noisy environments. By refining the multisensory feedback, we aspire to engage participants further and elicit a broader range of responses, reinforcing the MSD's potential to augment museum learning experiences.

Longitudinal studies tracking participants' engagement with their EmpowerBoxes over time are planned for future research. These studies will provide a more comprehensive understanding of the lasting impact of EmpowerBox on individuals with intellectual disabilities. It is also essential to assess how EmpowerBox affects communities, institutions, and societal perceptions of intellectual disabilities. This holistic approach will involve gathering feedback from various stakeholders, including support workers, educators, and family members, to evaluate the project's broader implications.

Future work in Artistic Fusion will evaluate user interaction with AI-powered real-time generation tools, allowing participants greater control over output customization. By giving users more power over the creative process, we aim to ensure that the technology is a truly collaborative tool, empowering individuals with intellectual disabilities to express their creativity and artistic vision more freely and effectively.

The future directions outlined in this doctoral dissertation represent an ambitious and innovative roadmap for advancing research in museums and creative experiences. By building on the foundations laid by this dissertation and addressing its limitations, future studies can significantly contribute to the field, enhancing the inclusivity, engagement, and educational value of museums for individuals with intellectual disabilities.

11

Conclusions

This doctoral dissertation has explored the intersection of digital accessibility, assistive technologies, and participatory design, with a focus on involving people with intellectual disabilities in co-designing knowledge-driven, engaging experiences with technology in the context of museums and a focus on informal learning and creativity. By engaging participants with intellectual disabilities in all design process steps, this research aimed to deeply understand their needs, preferences, and creative aspirations. The research journey, structured into four comprehensive parts, has yielded significant insights and methodological advancements in the field of HCI and accessibility.

Part I - Methodological Frameworks and Design: The doctoral dissertation began by emphasizing the critical role of improvisation and scaffolding techniques in adapting the design process to the unique requirements of participants with intellectual disabilities. This approach facilitated meaningful participation and ensured that the developed technologies resonated with the participants' needs. By adopting a participatory design approach, the study underscored the importance of involving participants as co-creators, thereby fostering a sense of ownership and relevance in the technology development process.

Part II - Digital and Interactive Technologies: The exploration of digital and interactive technologies – namely augmented reality through AIMuseum, accessible applications through ACCESS+, and social robots – demonstrated their potential to make museum content more understandable and engaging for individuals with intellectual disabilities. These technologies were instrumental in shifting the museum experience from a passive to an active engagement, where participants could interact with the content in novel and meaningful ways. The study highlighted the importance of customizing these technologies to meet the diverse needs and preferences of the target audience, ensuring a more inclusive and accessible cultural experience.

Part III - Creativity and Multisensory Integration: A pivotal aspect of this research was its focus on creativity and multisensory integration. Allowing users to engage with content through multiple senses with the MSD and Empowerbox. Also, Empowerbox and the use of AI for creative expression illustrated how technology could be leveraged to foster creativity and enable personal expression in a multisensory context. These initiatives emphasized the value of offering individuals with intellectual disabilities opportunities to express themselves creatively, thereby enhancing their engagement and interaction with cultural and educational content.

IV - Discussion and Conclusions: The last part of this doctoral dissertation includes the discussion and this chapter. The remaining research questions were addressed in the discussion, and the chapter focused on the key aspects: participatory design, engagement with digital and interactive technologies, creativity and multisensory inclusion, and the importance of communication.

Reflecting on the research questions, this doctoral dissertation has provided valuable contributions to HCI by offering methodological insights and practical applications for inclusivity in technology design. The study has advanced the understanding of how to involve people with intellectual disabilities in the co-design process, ensuring that the technologies developed are genuinely inclusive and engaging. Moreover, it has shed light on how digital and interactive technologies can be harnessed to make cultural institutions more accessible, thereby promoting the full integration of individuals with intellectual disabilities into cultural and creative experiences.

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