

SMART ASSISTIVE TECHNOLOGY FOR VULNERABLE PEOPLE IN PUBLIC SERVICES: A MULTI-APPROACH DIDACTIC FRAMEWORK

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ABSTRACT

This study presents a didactic framework for designing human-centred smart assistive technologies that improve accessibility in public services. The framework was developed to equip young designers with structured design methodologies, integrating ethnographic tools and embodied activities to foster a deeper understanding of accessibility barriers. The framework introduces students to disability-related challenges and guides them in developing smart products and services that address real-world needs. This work contributes to engineering and design education, ensuring future professionals can navigate social, economic, and experiential challenges in public service accessibility. By fostering empathy and user-centred awareness, the framework enabled a natural shift toward Product-Service Systems and collaborative consumption, demonstrating how assistive solutions can be integrated into public infrastructures rather than remaining individual, user-owned devices. Through a multi-phase process, students engaged in ethnographic research, embodied activities, and prototyping using various design tools, including AI-driven and actuator-based simulations. Evaluation through a Public vs. Personal/Interaction vs. Intervention matrix revealed that students gravitated toward service-embedded accessibility solutions. These findings confirm that structured design education can foster the development of integrated, sustainable, and human-centred assistive technologies, bridging the gap between inclusive design principles and real-world public service applications.

Keywords: Interaction design, design for accessibility, empathy-driven approach

1 INTRODUCTION

In recent years, conversations around accessibility and inclusion have gained momentum across political, social, and professional domains. Yet, despite this growing attention, many barriers still persist in the way public services, products, and technologies are designed for disabled people¹. Public services should be accessible to all citizens, but in reality, disabled and vulnerable individuals are often not considered in the design process, leaving them to navigate systems not built for them, such as public sites lacking nearby public transit stops, and trails and playgrounds not fully accessible to disabled people [1]. Exclusion, therefore, is not a consequence of disability but a failure of design that abides by the dominant perception of the individual/medical model (as opposed to social/relational model [2]). This issue is rooted in a deep inequity in how design resources, funding, and innovation are distributed, bending to today's attention economy [3] in which "marginalised individuals, communities, and movements rarely receive much of this attention" [4]. This imbalance means that while technology is advancing rapidly, those who could benefit the most from innovation are often left behind.

At the same time, Assistive Technologies (AT) are often designed as individual products, making them financially inaccessible or unavailable to many of their potential users [5]. However, the development of smart products must be understood within the broader shift toward Product-Service Systems (PSS), which promote collaborative consumption over individual ownership [6]. This approach lowers costs, increases accessibility, and supports sustainability. In the case of AT, such models could create alternative distribution systems, such as shared assistive devices in public spaces, subscription-based accessibility services, or embedded assistive solutions within urban infrastructure.

¹ Authors use the identity-first term "disabled people" rather than the people-first term "people with disabilities" to align with a social/relational model of disability.

Informed by Inclusive Design (ID) and Participatory Design (PD), this didactic framework adapts human-centred approaches to an educational setting through methods such as simulation and embodied research. Although direct co-design with disabled users is fundamental to real-world accessibility [7], the use of persona interviews and role-play aligns with the user-centred values emphasised in ISO 9241-210, particularly the focus on understanding user needs and designing for the full user experience. Additionally, the framework integrates perspectives from Design Justice, promoting equitable and situated design practices when addressing the needs of marginalised communities. In doing so, it calls for a shift in design education, introducing students to human-centred design not only as a method, but as a reflective, value-driven practice within the context of public service accessibility.

2 INTERACTION DESIGN COURSE: DESIGNING PUBLIC SERVICE INTERACTIONS FOR DISABLED AND VULNERABLE PEOPLE

The “Interaction Design Course”, a six-month course offered by Sapienza University of Rome during the third year of the Bachelor programme, was used as a platform to reach young designers. The course introduces smart objects through Design and Computer Engineering competencies, guiding students in their ideation and prototyping with Arduino (an open-source electronics platform based on easy-to-use hardware and software). Each year, the course's topic is chosen among pertinent contemporary issues with the goal of providing students with practical knowledge and abilities. In this case, the theme selected was “disabled and Vulnerable Users Experiences with Public Services: How to design Smart Assistive Technologies (SAT)”. While direct co-design with marginalised users is essential in real-world practice, this didactic framework does not involve disabled users directly. Instead, it serves as an educational tool to introduce students to disability issues and the design of SAT, equipping them with theoretical and practical skills to design with a more inclusive mindset. The course is structured into three main phases: Introduction to Disability Issues and Smart Technologies; Empathy-Building; Concept Definition and Prototyping. Through both theoretical lectures and practical activities, this framework provides a structured methodology for fostering empathy, accessibility awareness, and technological innovation, equipping future designers and engineers with the necessary knowledge and skills to create more equitable and accessible public services.

2.1 Phase 0: Introduction and start of the course

To start the activities, 20 young designers were divided into 11 groups (some in pairs, others individually). Each group was assigned a disability or vulnerability and a public service area to ensure diverse scenarios, though the combination of:

- Disabilities/vulnerabilities: ADHD, Amputation, Anxiety, Blindness, Cast/Brace, Deafness, Hearing Hypersensitivity, Mutism, Wheelchair.
- Public Services: Administrative Services, Educational Services, Health, Transport and mobility, Urban and Environmental Services.

2.2 Phase 1: Introduction to disability issues and Smart Technologies

The first phase of the course involves an introduction to the students' main topics: on the one hand the social issues related to the barriers and challenges faced by disabled and vulnerable individuals in their interaction with public services; on the other hand, the approach to Arduino, a technology essential for the conscious design and prototyping of smart products, though the simulation of its actuators.

a. Hif.AI module

To address social issues, the Hif.AI (Human Intelligence framing Artificial Intelligence) research module, previously tested in other didactic settings [8], was adopted. It served as an ice-breaking tool, helping students explore disability barriers from day one while fostering group brainstorming. The module alternates between AI- and HI-driven steps across six phases. It begins with Interview with Personas (AI), where ChatGPT helps explore disability challenges, followed by Storytelling (HI), where students create a three-scene storyboard. These are then visualised through Storyboard Illustrations (AI) using tools like Bing and Canva. Students develop design variations in Sketching the Product (HI), which are refined through Sketch Rendering (AI) with PromeAI. Finally, Concept Rendering (AI) generates final images, compared with previous sketches to assess design outcomes.

Students evaluated AI-generated outputs on Quality, Originality, and Utility (1–5 scale). Interview with Personas ranked highest in Quality and Utility, though less innovative. Storyboard Illustrations were most original with moderate quality and utility. Sketch and Concept Rendering scored lower efficiency

and innovation. The module averaged 3.1/5, reflecting a decent performance with room for improvement.

b. Actuator simulation

As an introduction to Arduino technology and its possible applications, experiments with light, vibration, and sound actuators were conducted. Students were shown a collection of case studies. Using mobile and web apps, they experimented with light, vibration, and sound signals to convey assigned emotions or sensations. The results of these experiments were illustrated on a duration/intensity graph to visualise their simulations.

2.3 Phase 2: Empathy building and service understanding

a. Workshop on “embodied” methods

During the one-day workshop “New scenarios for disabled people in public service contexts”, the participants used the “embodied” methods of designing such as role playing and bodystorming [9], and emergent dance-based methods such as scoring [10] and bodily involving prototyping [11]. The activities were divided into 2 main phases:

Reflection: Starting with an ice-breaking activity through scoring (generating improvised movement based on a set of parameters), students role-played the disability or vulnerability and the public service environment using the bodily involving prototyping. Then, they role-played the interaction of the user with the service (embodying the technologies or the service providers). The results were reported in an empathy map and discussed with the other groups.

Reimagination: students defined a concept and rough prototype of a SAT using tools such as bodystorming, brainstorming, and sketching. Finally, the young designers performed once again the user-service interaction, this time using the product they designed.

This phase was introduced by lectures about AT and frameworks of ID and PD. A disclaimer was made about the need in real contexts to include users in the design process, while simulation activities result from insufficient resources and time and should not be considered as a substitute for participatory and inclusive approaches.

b. Ethnographic toolkit

To fully understand the context of the public service reference and the different experiences of its users, participants were provided with an ethnographic toolkit. This toolkit was previously designed by the authors in different contexts [12], and for these activities, the three most appropriate tools were selected, including: General equipment (mapping the peculiar and most useful artifacts in the studied environment, noting their quantities and private or public ownership); Artifact analysis (a detailed qualitative analysis of the most relevant artifacts based on aesthetics, interaction, materials, and location); Fly-on-the-wall observation and behavioural mapping (requires the designer’s detached observation of the activities, while taking notes of the actions, interactions, and events onto a map of the site). The students visited their assigned public service, such as post offices, pharmacies, medical waiting rooms, and train and metro stations, where they used the toolkit to observe and map objects, actions, and behaviours. The tools were filled on-site with sketches and notes, then digitalised in a specific layout. At the end of the course, the students were asked to evaluate the toolkit using the SUS: the result was 77.0, suggesting that the system is well-designed, user-friendly, and above average in usability.

2.4 Prototyping Smart Assistive Technologies

The third phase is dedicated to the definition of a concept and final prototyping of a SAT that allows disabled users to contrast or reduce barriers in the use of public services. In this phase, the young designers analysed the results of the previous phases, reviewing the insight from the interview with the AI-generated personas, the empathy map from the embodied activities, and the ethnographic research, and turned their ideas into prototypes using the skills acquired. This phase included several review sessions with Design and Computer Engineering teachers to arrive at the final proposal for each group.

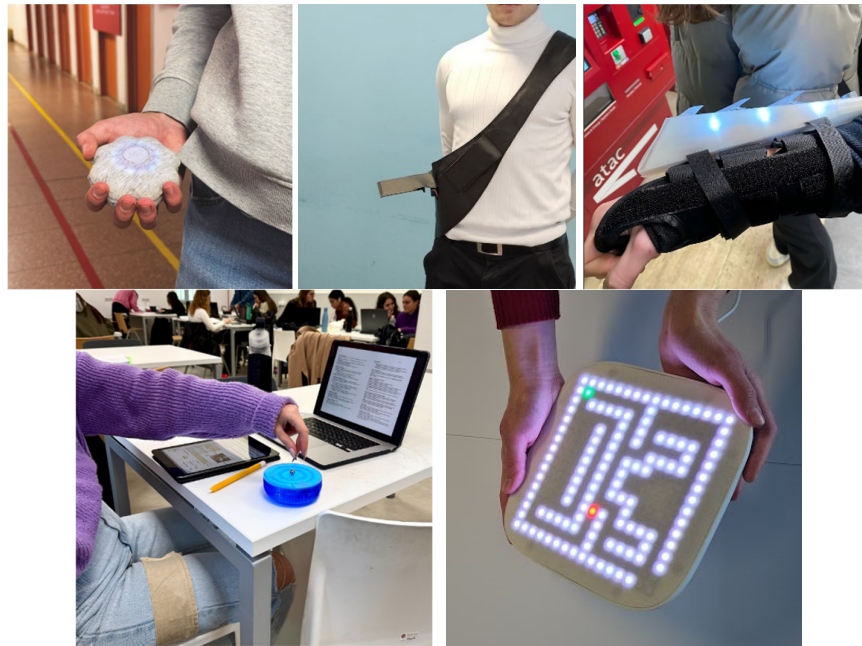


Figure 1. Some examples of SAT designed during the course. Top row: Blindness in hospitals (by G. Navarro Andreani & L. Tiberi); Upper-limb amputee at turnstiles (by F. Fragione & A. Grossi); Cast/brace in crowded transports (by S. Piccioni & G. Sorrenti). Bottom row: ADHD in libraries (by L. Rochira & C. Zamparelli); Deafness in post offices (by S. Luccone & G. Piccolomini)

3 RESULTS AND DISCUSSION

With the aim for a shift toward collaborative consumption over individual ownership, as mentioned in the introduction of this article, the insights from the course can be categorised into two key dimensions: "public" vs. "personal". This distinction applies to both interactions (how users experience and navigate accessibility challenges) and interventions (the types of solutions designed to address these challenges).

Public vs. Personal in Interactions: Public Interactions refer to how users engage with the external service environment - for example, how a deaf person receives announcements at a ticket counter. These interactions are shaped by the accessibility (or lack thereof) of the service interface itself. Personal Interactions are based on an individual's internal experience of accessibility barriers - for example, a person with ADHD struggling to focus in a library. These challenges are more subjective, based on how a person perceives and reacts to their environment rather than on physical service infrastructure.

Public vs. Personal in Interventions: Public, On-Site Solutions are integrated into the service environment, making accessibility part of the shared public infrastructure rather than individual responsibility. For example, a train station platform that provides real-time visual announcements for deaf users ensures universal access without requiring personal assistive devices. User-Owned, Individual Solutions are assistive devices that a person must carry or wear to access services. These solutions address personal barriers but require the user to own, manage, and use the technology themselves. For instance, a noise-cancelling headset that automatically activates in response to high noise levels is a personal tool that helps an individual rather than a public adaptation that benefits all users in a space.

Table 1. The projects systematised in the Matrix Public vs Personal / Interaction vs Interventions

Interaction Type	Public, On-Site Intervention (Service-Embedded Solutions)	User-Owned, Individual Intervention (Personal Assistive Devices)
Public Service	1. Train platform-activated display for	1. Shoulder-activated strap for hands-

<p>Interface (Addressing environmental barriers in public services)</p>	<p>deaf users. 2. Post office turn-taking device for deaf users 3. Metro station tile with directional speaker for blind users. 4. Hospital navigation device for blind users. 5. Interactive “mannequin” for mute users in pharmacies.</p>	<p>free access to transport and payment cards. 2. Cast-protecting device for crowded public transport.</p>
<p>Individual Personal Experience (Addressing personal mobility, sensory, or cognitive barriers)</p>	<p>(No solutions in this quadrant since all personal experience challenges were addressed through individual, user-owned interventions.)</p>	<p>1. Automatic noise-cancelling headphones for hypersensitive users. 2. Focusing device for ADHD users in libraries. 3. Anti-anxiety bracelet for post office users. 4. Wheelchair automatic braking system.</p>

This framework allows us to analyse whether the resulting AT are embedded within public systems or designed as personal tools, ultimately shaping how accessibility is approached—either as a shared, service-wide responsibility or as an individual adaptation challenge. This reveals how disability is perceived by young designers in their creative process, directing future improvement ID education. Most interventions focus on either public service interfaces or personal experience challenges, with few hybrid solutions. The upper-left quadrant (public on-site solutions for service interfaces) contains the majority of interventions, reflecting a tendency to embed AT into public infrastructure. The lower-right quadrant (individual-owned solutions for personal experience challenges) is also well-populated, meaning that many solutions still assume individual responsibility for accessibility rather than designing for collaborative public accessibility. The lower-left quadrant (public solutions for individual experiences) is empty, suggesting that no designed interventions addressed personal barriers through publicly available shared resources.

During the design process, students were asked to justify their design decisions based on insights from the research phases and were evaluated on this coherence. While manufacturability wasn’t formally assessed, trade-offs between accessibility, usability, and production were discussed during reviews. Some students selected materials and mechanisms based on production feasibility, especially at the prototyping stage.

While the framework does not explicitly follow ISO 9241-210, it aligns with its core principles, including understanding user needs, involving users indirectly through simulation, and evaluating outcomes iteratively. Unlike traditional HCD models, this framework was tailored for an educational context with limited access to real users, focusing instead on embodied and simulated approaches. Student engagement suggested that this method fostered a strong sense of empathy and critical awareness; many reported feeling more confident in addressing accessibility barriers and more capable of translating abstract insights into tangible design solutions.

4 CONCLUSIONS

This study’s multi-approach didactic framework aims to educate young designers on human-centred SAT, fostering ID innovation. Through ethnographic research, technological experimentation, and embodied activities, students identified service barriers and developed assistive solutions to improve accessibility in public services.

As a key finding, even without direct instructor input, students naturally gravitated toward embedded AT rather than relying solely on personal, user-owned devices. This shift aligns with PSS and collaborative consumption, reinforcing the idea that accessibility should be a shared, systemic responsibility rather than an individual burden. The student projects reflect a growing inclination toward public, on-site assistive solutions, integrating accessibility directly into service infrastructures (i.e., a

guiding tile that provides auditory guidance for blind travellers and an interactive turn-taking system at post offices). These innovations suggest that designers are beginning to see accessibility as an integrated service rather than an add-on tool.

However, many solutions still depend on personal devices, particularly in addressing sensory and cognitive barriers. For instance, an anxiety bracelet for stress management and a meditation device for ADHD students assume that accessibility is an individual responsibility rather than a publicly available resource. This raises a crucial question: Can personal assistive solutions be reimagined as public, on-site services? Instead of requiring each person to own an anxiety bracelet, could calming stations be introduced in high-stress environments like post offices? Could public transport hubs offer on-demand noise-reduction spaces instead of assuming users must find their own solution? Hybrid models that bridge individual needs with public accessibility could reduce economic barriers and create more equitable AT. Integrated, inclusive accessibility must remain a priority in a society committed to collective well-being. ID and PD frameworks, alongside movements like Disability Justice, provide essential guidelines to ensure that public services become truly accessible. This framework demonstrated that, with proper methods, young designers can drive this transformation.

Moving forward, this study lays the groundwork for future research on how public services can integrate assistive solutions at a systemic level. While students' organic shift toward embedded accessibility is promising, further refinement is needed to ensure AT prioritise shared access and universal inclusion. By fostering this educational shift, we move toward a future where AT are no longer individualised adaptations but embedded components of an inclusive, human-centred public service ecosystem.

REFERENCES

- [1] Firkin C. J., Rechner L. and Obrusnikova I. Paving the Way to Active Living for People with Disabilities: Evaluating Park and Playground Accessibility and Usability in Delaware. *Delaware Journal of Public Health*, vol. 10, no. 1, pp. 74-83, Mar. 2024. doi: 10.32481/djph.2024.03.09.
- [2] UPIAS. Fundamental Principles of Disability. Available: <https://disability-studies.leeds.ac.uk/wp-content/uploads/sites/40/library/UPIAS-fundamental-principles.pdf> [Accessed on 2024, 25 November].
- [3] Davenport T. H. and Beck J. C. *The Attention Economy*, 2001 (Ubiquity, May).
- [4] Costanza-Chock S. *Design Justice: Community-led Practices to Build the Worlds We Need*, 2020 (The MIT Press).
- [5] Tangcharoensathien V., Witthayapipopsakul W., Viriyathorn S. and Patcharanarumol W. Improving access to assistive technologies: challenges and solutions in low- and middle-income countries. *WHO South-East Asia Journal of Public Health*, vol. 7, no. 2, p. 84, 2018. doi: 10.4103/2224-3151.239419.
- [6] Leismann K., Schmitt M., Rohn, H. and Baedeker C. Collaborative Consumption: Towards a Resource-Saving Consumption Culture. *Resources*, vol. 2, no. 3, pp. 184-203, 2013. doi: 10.3390/resources2030184.
- [7] Perry M., Cotes L., Horton B. P., Kunac R., Snell I., Taylor B. and Devan H. 'Enticing' but not necessarily a 'space designed for me': Experiences of urban park use by older adults with disability. *International Journal of Environmental Research and Public Health*, vol. 18, no. 2, p. 552, 2021. doi: 10.3390/ijerph18020552.
- [8] Malakuczi V., Ershova M., Gentile A., Gironi C., Saviano M. and Imbesi L. Design in dialogue: AI as an aid of imagination for future scenarios. In *DRS2024: Boston, 23–28 June, Boston, USA*, C. Gray, E. Ciliotta Chehade, P. Hekkert, L. Forlano, P. Ciuccarelli, and P. Lloyd, Eds., 2024. doi: 10.21606/drs.2024.1171.
- [9] Hanington B. and Martin B. *Universal Methods of Design: 100 Ways to Explore Complex Problems, Develop Innovative Strategies, and Deliver Effective Design Solutions*, 2012.
- [10] Loke L. and Robertson T. Studies of dancers: Moving from experience to interaction design. *International Journal of Design*, 2010.
- [11] Anderson-Schaeffer J. and Palmgren M. Prototyping in the in-between: A Method for Spatial Design Education. 2016.
- [12] Malakuczi V., Giambattista A., Gentile A. and Ershova M. Comunità sportive come aggregatori della diversità nel contesto urbano. Indagine etnografica e sviluppo di un modello di coinvolgimento. In *Design per la diversità. Atti della conferenza annuale della Società Italiana di Design, Pescara, 12-13 giugno 2023*, pp. 324-334.