Framework for using
Co-Design.

Collaborative Co-Design: Empowering Occupational Therapists, Engineers, and Clients to Create 3D Printed Devices

Abraham Gonzalez Delgado

Content Outline

The Essence of Co-Design

Introduction.

The integration of co-design principles with advanced 3D printing technology presents a transformative opportunity in the development of assistive devices for individuals with disabilities.

The Department of Occupational Therapy, recognizing the potential of these innovations, seeks to leverage its high-quality 3D printer and the growing repository of open-source plans available online. This initiative aims to empower Manitoba occupational therapists and rehabilitation engineers to co-design personalized assistive devices, directly addressing the unique needs and preferences of their clients.

The Essence of Co-Design.

Co-design is a collaborative approach that involves all stakeholders, clients, therapists, and engineers, working together throughout the design process (Aflatoony et. Al 2021). Unlike traditional design methods where the end-user's input is often minimal or absent, co-design ensures that the users' voices are central (Sarmiento-Pelayo 2015).

This participatory method not only enhances the usability and relevance of the final product but also promotes a sense of ownership and satisfaction among users (Romani et al. 2020).

In the context of assistive devices, co-design becomes particularly crucial. Individuals with disabilities face diverse and specific challenges that standardized products may not adequately address. By actively involving these individuals in the design process, the resulting devices are better tailored to their functional and aesthetic needs, significantly improving their quality of life (Gherardini et al. 2020).

The Role of 3D Printing.

3D printing, also known as additive manufacturing, allows for rapid prototyping and customization, making it an ideal tool for the co-design process (Robinson et al. 2018). This technology enables the creation of intricate and personalized designs that would be difficult or impossible to achieve with traditional manufacturing methods (Day et al. 2018). For occupational therapists and rehabilitation engineers, 3D printing offers the flexibility to quickly iterate on designs based on user feedback, ensuring that the final product is both functional and user-friendly (Degerli et al. 2022).

Objectives of the Framework.

The primary objective of this framework is to establish a structured and effective process for co-designing assistive devices using 3D printing. It aims to facilitate meaningful collaboration among clients, therapists, and engineers, ensuring that each stakeholder's input is valued and integrated into the design. The framework outlines clear steps and protocols to guide the co-design process from initial needs assessment to final production, ensuring that the devices developed are practical, personalized, and of high quality.

This participatory approach aims to empower users by valuing their input and fostering a sense of ownership over the final product by actively involving individuals with disabilities in the design process to ensure that their unique needs and preferences are central to the development of assistive devices.

Establishing clear protocols for communication, feedback, and iterative improvement to ensure that the design process is efficient and effective will facilitate a collaborative environment where users, occupational therapists, and engineers work together seamlessly.

We can maximize the potential of 3D printing to create customizable and innovative assistive devices. This technology allows for rapid prototyping and iterative testing, enabling the development of devices that are precisely tailored to the functional and aesthetic needs of users.

The ultimate aim is to create solutions that significantly impact users' ability to perform daily activities and participate fully in their communities by providing them with assistive devices that improve their mobility, independence, and overall well-being.

It’s important to consider creating a sustainable and scalable model for the co-design and production of assistive devices. This includes developing training materials, documentation, and best practices that can be used by other occupational therapy departments and rehabilitation centers.

Scope and Impact

The scope of this framework encompasses a wide range of assistive devices, including but not limited to mobility aids and adaptive tools. By defining clear roles and responsibilities for each participant, the framework ensures that the co-design process is well-structured. The anticipated impact is significant: improved user satisfaction, enhanced device usability, and meaningful improvements in clients' daily activities.

Section 2.

Workforce Groups in the Co-Design Process

The collaborative effort of users, Occupational Therapist (OTs), and engineers results in assistive devices that are highly personalized, functional, and supportive of the users' therapeutic and daily living needs. This integrated approach ensures that the devices are not only technically reliable and functional, but also aligned with the users' lifestyles and rehabilitation goals, leading to better adoption and improved quality of life for individuals with disabilities (Aflatoony et. Al 2021).

Users (Clients)

Process:

- **Needs Assessment:** Users provide critical information about their daily activities, challenges, and specific requirements for assistive devices through interviews, surveys, and observational studies.

- **Ideation and Conceptualization:** Users participate in brainstorming sessions to share their ideas and preferences, helping shape the initial design concepts.

- **Prototyping:** Users interact with early prototypes, offering feedback on functionality, comfort, and usability.

- **Testing and Feedback:** Users test the devices in real-world scenarios and provide detailed feedback to inform iterative improvements.

- **Final Production:** Users are involved in the final evaluation of the device to ensure it meets their needs and expectations.

- **Future Assessment:** Continuous evaluation of the device after months of daily use, to ensure that the device is still meeting the expectations or requires adaptation.

Importance:

- **Personalized Solutions:** Users' input ensures that the devices are tailored to their unique needs and preferences, leading to higher satisfaction and better usability (Sarmiento-Pelayo 2015).

- **Empowerment:** Involving users in the design process empowers them by valuing their experiences and perspectives, fostering a sense of ownership over the final product (Schwartz et al. 2020).

- **Enhanced Adoption:** Devices co-designed with user input are more likely to be accepted and used consistently, improving the users' quality of life (Romani et al. 2020).

Occupational Therapists (OTs)

Process:

- **Needs Assessment:** OTs conduct comprehensive assessments to identify clients' functional limitations and therapeutic goals, translating these into design requirements.
  - This can be done by following the HAAT model, which is used to understand and guide the design and use of assistive technologies (Cook and Polgar 2015).
  - It consists of four main components: the human, which focuses on the individual's capabilities, preferences, and experiences; the activity, which represents the tasks the individual

needs or wants to perform; the assistive technology, which includes the devices or systems used to enhance the individual's abilities; and the context, which refers to the environment in which the assistive technology is used, including physical, social, and cultural factors.

- **Ideation and Conceptualization:** OTs contribute clinical insights during brainstorming sessions, ensuring that design ideas align with therapeutic objectives.

- **Prototyping:** OTs collaborate with users and engineers to evaluate prototypes, providing feedback on their therapeutic effectiveness and usability.

- **Testing and Feedback:** OTs monitor the use of prototypes in real-world settings, collecting data on their impact on clients' daily activities and overall well-being.

- **Final Production:** OTs ensure that the final device supports the clients' therapeutic needs and facilitates their rehabilitation goals.

Importance:

- **Clinical Expertise:** OTs bring essential clinical knowledge to the co-design process, ensuring that assistive devices are not only functional but also support therapeutic outcomes.

- **Client Advocacy:** OTs advocate for the clients' needs and preferences, helping to mediate between users and engineers to achieve optimal design solutions.

- **Usability and Safety:** OTs help ensure that the devices are safe, easy to use, and effective in meeting the clients' therapeutic goals.

Engineers (Rehabilitation Engineers)

Process:

- **Needs Assessment:** Engineers translate the clinical and user requirements identified during assessments into technical specifications.

- **Ideation and Conceptualization:** Engineers contribute technical expertise during brainstorming sessions, evaluating the feasibility of design ideas and suggesting innovative solutions.

- **Prototyping:** Engineers use CAD software and 3D printing technology to create physical prototypes based on the conceptual designs.

- **Testing and Feedback:** Engineers refine prototypes based on feedback from users and OTs, addressing any technical issues and improving the design.

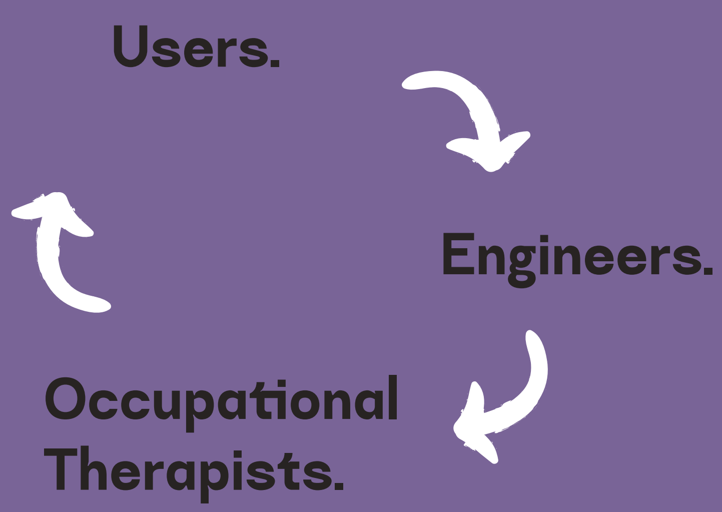
- **Final Production:** Engineers oversee the final production of the assistive devices, ensuring they meet all technical standards and specifications.

Importance:

- **Technical Expertise:** Engineers provide the technical skills necessary to bring design concepts to life, ensuring that the devices are structurally sound and functional.

- **Innovation:** Engineers leverage advanced technologies, such as 3D printing, to create innovative and customized solutions that meet the specific needs of users.

- **Iterative Improvement:** Engineers play a crucial role in the iterative process of prototyping and refining designs, ensuring that the final product is optimized for performance and usability.



Interrelationships in the Co-Design Process

Effective stakeholder involvement is crucial to the success of the co-design process (Aflatoony et. Al 2020). This section outlines the protocols and strategies for engaging clients, occupational therapists (OTs), and engineers throughout the development of assistive devices. Ensuring robust communication and collaboration among these groups will enhance the quality and usability of the final products (Slattery et al. 2020).

Client-Centric Approach

Initial interactions with clients set the foundation for a successful co-design process. These steps ensure that clients' needs and preferences are understood and prioritized:

- **Initial Assessments:** Conduct thorough initial assessments to gather detailed information about clients' disabilities, daily activities, challenges, and specific needs. This can include interviews, surveys, and observational studies.

- **Client Interviews:** Organize one-on-one interviews with clients to understand their personal goals, preferences, and expectations for the assistive devices. These interviews provide valuable insights that guide the design process.

- **Family and Caregiver Involvement:** Involve family members and caregivers in the preliminary meetings to gather additional perspectives and ensure a holistic understanding of the clients' needs.

- **User-Centered Design:** The central role of users ensures that their needs and preferences drive the design process, with OTs and engineers working together to translate these into functional devices.

- **Iterative Development:** The iterative nature of the process, with continuous testing and feedback, allows for the refinement of designs based on real-world use, ensuring that the final products are effective and user-friendly. Scheduling regular check-ins with clients to discuss progress, gather feedback, and address any concerns, helps to keep clients informed and engaged.

- **Inclusive Design Sessions:** Organize design sessions where clients actively participate in brainstorming, prototyping, and testing phases. This inclusive approach ensures that clients' voices are heard and incorporated into the final designs.

Communication Strategies

Effective communication is vital for collaboration among stakeholders. The following strategies facilitate regular and productive interactions:

- **Regular Meetings:** Regularly scheduled meetings and workshops facilitate communication among users, OTs, and engineers, ensuring continuous feedback and collaboration.

- **Workshops and Brainstorming Sessions:** Organize workshops and brainstorming sessions to encourage creative thinking and collaborative problem-solving. These sessions provide opportunities for stakeholders to share ideas and develop innovative solutions.

- **Progress Reviews:** Conduct periodic progress reviews to assess the project's status, discuss challenges, and plan the next steps. These reviews help ensure that the project stays on track and addresses any issues promptly.

Use of Collaborative Tools and Platforms

Leveraging technology to facilitate communication and collaboration is essential for an effective co-design process. The following tools and platforms can enhance stakeholder engagement

- **Shared Platforms:** Collaborative tools, such as shared documents and online platforms, enable all stakeholders to contribute ideas, review designs, and provide feedback throughout the process. These meetings can be weekly or biweekly, depending on the project's needs.

- **Design Software:** Employ design software like CAD (Computer-Aided Design) programs that allow OTs and engineers to create and share digital prototpes. Clients can review and provide feedback on these prototypes, facilitating iterative improvements.

- **Virtual Meeting Platforms:** Use virtual meeting platforms like Zoom or Google Meet to conduct meetings and workshops, especially when in-person interactions are not feasible. These platforms support video conferencing, screen sharing, and interactive discussions.

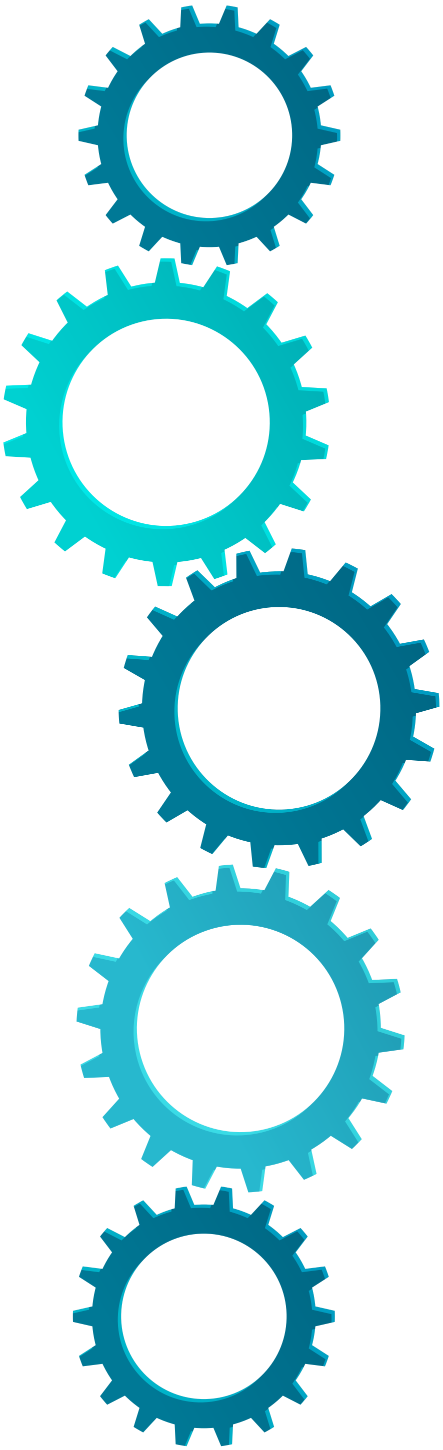
- **Feedback Platforms:** Implement feedback platforms, such as SurveyMonkey or Google Forms, to collect structured feedback from clients. These platforms allow for easy analysis and integration of feedback into the design process.

Section 3.

Design Process Phases

The Co-Design Gear System

Envision the design process as a system of interconnected gears, where each phase is a gear that turns in sync with the others, representing the nature of developing assistive devices.



GEAR 1: Needs Assessment

Methods: Interviews, surveys, observations.
Outcome: Initial understanding of client needs.
Function: This gear initiates the process by gathering essential information, turning and engaging the next gear.

GEAR 2: Ideation and Conceptualization

Methods: Brainstorming with sketches, storyboards, digital models.
Outcome: Generating and prioritizing ideas.
Function: As Gear 1 turns, it drives Gear 2 to begin conceptualizing ideas based on the assessed needs. Feedback from this phase may cause Gear 1 to adjust slightly, refining needs.

GEAR 3: Prototyping

Methods: CAD and 3D printing to develop initial prototypes.
Outcome: Early prototypes developed.
Function: The turning of Gear 2 powers Gear 3, leading to the creation of tangible prototypes. Interaction with these prototypes might feedback into Gear 2, influencing further ideation.

GEAR 4: Testing and Feedback

Methods: Real-world usability tests, detailed feedback collection.
Outcome: Iterative improvements.
Function: Gear 3's movement engages Gear 4, initiating testing and feedback collection. The results from this phase can turn back into Gear 3 for prototype adjustments and into Gear 2 for further ideation refinement.

GEAR 5: Final Production

Methods: Refinement for safety and quality, client training.
Outcome: Final, user-ready assistive devices.
Function: As the previous gears turn, Gear 5 is driven to finalize the design, ensuring all adjustments and improvements are integrated. This gear's smooth operation ensures that the entire system functions effectively, producing high-quality assistive devices.

1 Needs Assessment

The design process for developing assistive devices begins with a thorough needs assessment, which is crucial for understanding and accurately defining the requirements of the end-users (Thorsen et al. 2024). This phase involves several key activities to gather comprehensive information about the clients' needs and translate these into specific design parameters.

Methods for Assessing Client Needs

Interviews

One-on-one interviews with clients allow for a deep understanding of their specific needs, preferences, and challenges. These conversations help gather qualitative data and personal insights that are vital for the design process.

Example: An interview with a client who uses a wheelchair might reveal their difficulty in accessing items on high shelves, leading to the identification of a need for a reach-assist device.

Surveys

Structured surveys can be distributed to a larger group of clients to collect quantitative data on common needs and preferences. This method helps identify trends and common issues that multiple clients may face.

Example: A survey among a group of clients with limited hand mobility might show a widespread need for devices that assist with gripping and holding objects.

Observations

Observing clients in their daily environments provides real-world insights into the challenges they face and the context in which the assistive device will be used. This method helps in understanding the practical aspects of the clients' interactions with their surroundings.

Example: Observing a client at home might reveal difficulties in moving between rooms, indicating a need for mobility aids such as ramps or automated doors.

Translation of Needs into Design Requirements

Once the data from interviews, surveys, and observations are collected, the next step is to translate these needs into specific design requirements. This involves:

Identifying Key Needs

Analyzing the collected data to identify the most critical needs that the assistive device should address.

Example: From the interview with the wheelchair user, the key need identified is the ability to access items at different heights.

Setting Design Goals

Defining clear and measurable goals for the design based on the identified needs. These goals should be specific, achievable, and relevant to the clients' requirements.

Example: A design goal might be to create a reach-assist device that can extend the user's reach by at least 2 feet and support objects up to 5 pounds.

Developing Design Specifications
Creating detailed design specifications that outline the functional and performance criteria the device must meet. These specifications guide the subsequent phases of the design process.

Example: Specifications for the reach-assist device might include material durability, weight capacity, ease of use, and ergonomic design considerations.

SMART Goal-Setting

Doran (1981) first introduced the SMART goal-setting framework as a structured approach to defining clear and actionable objectives. It ensures that each goal is Specific, Measurable, Achievable, Relevant, and Time-bound.

Specific
Goals should be clear and specific, answering the questions of who, what, where, when, why, and how. Collaborate with stakeholders (clients, occupational therapists, engineers) to identify the exact needs of the clients and the specific outcome the assistive device should achieve.
t

Measurable
Goals should have criteria for measuring progress and success. Define clear metrics to assess whether the goal has been achieved.

Achievable
Goals should be realistic and attainable, considering the available resources and constraints. Ensure the goal is feasible given the time, budget, technology, and skills available.

Relevant
Goals should matter and be aligned with other relevant objectives. Ensure the goal aligns with the overall purpose of improving clients' daily activities and quality of life.

Time-bound
Goals should have a clear timeline, including a start and end date. Set a realistic deadline for achieving the goal to maintain focus and motivation.

Example:
Develop a reach-assist device for wheelchair users.

- **Specific:** The device should help wheelchair users reach items up to 2 feet above their head.
- **Measurable:** Test with 10 users, must support objects up to 5 pounds.
- **Achievable:** Use current 3D printing technology, complete within 6 months.
- **Relevant:** Improve daily accessibility for wheelchair users.
- **Time-bound:** Design and prototype within 3 months, complete initial testing in 6 months.

2 Ideation and Conceptualization

Brainstorming Sessions with All Stakeholders

The ideation phase begins with inclusive brainstorming sessions that involve all stakeholders, including clients, occupational therapists, and engineers. These sessions are designed to harness the collective creativity and expertise of the team.

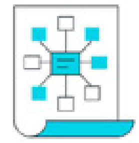
Techniques such as mind mapping, free writing, and group discussions are employed to generate a broad range of ideas. Encouraging open dialogue and ensuring that all voices are heard are critical to this process.

Affinity Diagrams: Use affinity diagrams to organize ideas generated during brainstorming into clusters based on their natural relationships. This can help in identifying key themes or patterns.

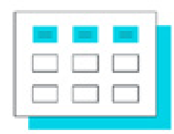
Example: In a brainstorming session for a wheelchair accessory, clients expressed a need for a detachable tray that could be used for both eating and using a laptop. Occupational therapists provided insights on ergonomic requirements, while engineers discussed material options and attachment mechanisms.

Use of Visual Aids

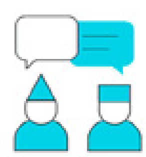
Here are examples, ideas, or tools that could be used during ideation meetings in a co-design process for assistive devices:



- **Mind Mapping:** Use a mind map to explore and visualize the relationships between different ideas and concepts (Moggridge 2006).
    - Write a problem you'd like to target at the center, write down other words, signs, connecting with the initial point, or linking one to each other.



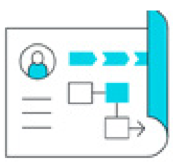
- **Card Sorting:** Involve participants in sorting cards that represent different features, needs, or design elements. Ask the participant to sort them prioritizing by importance or relevance



- **Role-Playing and Scenario Building:** Engage participants in role-playing scenarios to better understand the client's daily challenges. This can reveal insights into how an assistive device could be designed to meet their needs.
- Develop detailed scenarios that describe specific situations in which the assistive device would be used. These scenarios help guide the brainstorming process by providing context.

- **Sketching Sessions:** Encourage participants to draw their ideas on paper. Even simple sketches can help convey concepts that may be difficult to describe verbally.

- **Conceptual Prototyping:** Create quick, low-fidelity prototypes using materials like cardboard, clay, or foam to physically explore different design ideas. This can lead to immediate feedback and new ideas.



- **User Journey Mapping (Howard 2014):** Map out the participant's experience with a potential assistive device from start to finish. This helps identify critical touchpoints where the design can make the most impact.

Prioritization of Ideas

Once a variety of ideas have been generated, the team works together to prioritize them based on factors such as feasibility, potential impact, cost, and alignment with client needs.

Techniques such as voting, ranking, and the use of decision matrices can help in systematically evaluating and selecting the most promising ideas for further development.

Decision Matrix

It is a valuable tool used to evaluate and prioritize different design ideas based on a set of predefined criteria. It helps teams make objective, informed decisions by quantifying and comparing various options.

1. **Identify Criteria:** Begin by listing the criteria that are important for evaluating the design ideas. These could include factors such as feasibility, cost, impact, ease of implementation, user satisfaction, and alignment with client needs.
2. **Assign Weights:** Assign a weight to each criterion based on its importance. The weights are typically on a scale (e.g., 1 to 5), where a higher number indicates greater importance.
3. **Rate Each Idea:** For each design idea, rate how well it meets each criterion using a consistent scale (e.g., 1 to 10). This rating reflects how strongly the idea aligns with or fulfills each criterion.
4. **Calculate Scores:** Multiply the rating for each criterion by its corresponding weight to calculate the weighted score for each idea. Then, sum the weighted scores to get a total score for each design idea.
5. **Compare and Prioritize:** Compare the total scores of all the design ideas. The idea with the highest score is typically considered the most promising and is prioritized for further development.

3 Prototyping

Development of Initial Prototypes Using CAD Software and 3D Printing

In the prototyping phase, selected ideas are transformed into tangible prototypes. Computer-Aided Design (CAD) software is used to create detailed designs, which are then printed using the 3D printer.

This phase may involve creating multiple iterations of the prototype to explore different aspects of the design and refine details.

Example: The team created several versions of the wheelchair tray prototype, experimenting with different materials and attachment mechanisms. CAD software was used to make precise adjustments to the design before each 3D print.

Interaction with Prototypes and Initial Feedback

The initial prototypes are shared with clients for hands-on interaction. This allows clients to experience the design first-hand and provide immediate feedback on aspects such as usability, comfort, and functionality.
This feedback is crucial for identifying any issues or areas for improvement early in the process.

Example: Clients tested the various tray prototypes by attaching them to their wheelchairs and using them in different scenarios, such as during meals and while working on a laptop. Their feedback highlighted the need for a more stable attachment and a non-slip surface.

4 Testing and Feedback

Usability Tests in Real-World Settings

The next phase involves conducting usability tests with the prototypes in real-world settings. Clients use the prototypes in their daily activities to assess their performance and identify any practical challenges.

Occupational therapists and engineers observe these tests and gather detailed feedback on the device's functionality, ease of use, and effectiveness.

Example: The wheelchair tray prototypes were tested in various settings, such as at home, in the office, and outdoors. These tests helped identify practical issues like difficulties in attaching and detaching the tray and its stability on uneven surfaces.

Collection of Detailed Feedback and Iterative Improvements

Detailed feedback from clients is collected through interviews, surveys, and direct observation. This feedback is analyzed to identify common themes and specific issues that need to be addressed.

The design team uses this information to make iterative improvements to the prototypes. This may involve revisiting the ideation and prototyping phases to refine the design further.

Example: Feedback from the usability tests led to several iterations of the tray design, including adjustments to the attachment mechanism for easier use and the addition of a locking feature to improve stability.

5 Final Production

Refinement of the Final Design

After several rounds of testing and feedback, the final design is refined to address any remaining issues and enhance the overall quality and functionality of the device.

This phase ensures that the design is robust, user-friendly, and meets all safety and quality standards.

Example: The final version of the wheelchair tray incorporated all the improvements from the iterative feedback process, resulting in a design that was both functional and user-friendly.

Ensuring Safety and Quality Standards

The final production phase involves rigorous testing to ensure that the device complies with all relevant safety and quality standards. This may include mechanical testing, user trials, and certification processes.

Ensuring the highest standards of safety and quality is essential to provide clients with reliable and effective assistive devices.

Example: The final tray design underwent mechanical testing to ensure it could withstand regular use and accidental impacts. It also passed safety certification to confirm it met all required standards.

Training and Support for Clients

Once the final device is ready, clients are provided with training and support to ensure they can use it effectively. This may include instructional materials, hands-on training sessions, and ongoing support from occupational therapists.

Ensuring that clients are comfortable and confident in using the device is crucial for its successful adoption and long-term effectiveness (Aflatoony et. Al 2021).

Example: Clients received a user manual with detailed instructions on how to attach, use, and maintain the tray. Additionally, occupational therapists conducted training sessions to demonstrate proper usage and answer any questions.

Section 4.

Evaluation Metrics

The success of the co-design framework for assistive devices relies on comprehensive evaluation metrics that assess the process and outcomes (Gherardini et al. 2020). These qualitative and quantitative metrics ensure that the devices not only meet the immediate needs of clients but also provide long-term benefits.

There are a number of different standarized tools designed to assess the satisfaction of users with their assistive devices and related services.

1 User Satisfaction

Post-use Surveys and Interviews

To measure user satisfaction, detailed post-use surveys and interviews are conducted with clients. These instruments capture clients' experiences and perceptions of the assistive devices.

Surveys may include quantitative measures such as Likert scale ratings (Ankur et Al. 2015) on aspects like satisfaction with the device's performance, ease of use, and comfort.

Example: A survey might ask clients to rate their satisfaction with the wheelchair tray on a scale from 1 to 5, with additional open-ended questions allowing them to elaborate on their ratings.

Assessment of Overall User Experience

In addition to surveys and interviews, a holistic assessment of the overall user experience is conducted. This includes analyzing how well the device integrates into the clients' daily routines and how it impacts their overall quality of life.

Example: An interview with a client might explore how the tray has affected their ability to eat meals independently or use a laptop comfortably, providing a broader picture of the device's impact.

QUEST (Quebec User Evaluation of Satisfaction with Assistive Technology)

According to Demers et al (2002), QUEST is widely used in both clinical and research settings.

The tool evaluates two primary dimensions:

1. Satisfaction with Assistive Device – focusing on aspects like effectiveness, safety, comfort, and ease of use.
2. Satisfaction with Services – assessing the quality of services provided during the acquisition, fitting, and maintenance of the assistive technology.

QUEST 2.0, a revised version, consists of 12 items, divided between these two dimensions:

1. 8 items about the assistive device (e.g., durability, ease of adjustment).
2. 4 items about the services (e.g., delivery, follow-up services).

Users rate their satisfaction on a 5-point Likert scale, and the evaluation helps guide improvements in both product design and service delivery.

PIADS (Psychosocial Impact of Assistive Devices Scale)

Jutai and Day (2002) explain how PIADs work as a tool used to measure the effects of assistive devices on the psychological and social well-being of users. It evaluates the user's perception of how their assistive technology influences their quality of life across three domains: competence, adaptability, and self-esteem.

PIADS concentrates on the psychological and social effects of assistive devices. The scale is designed to capture the user's subjective experience and the personal impact of the device in their daily life.

Competence: This domain measures how much the assistive device impacts the user's sense of skill, ability, and independence. It evaluates whether the device makes the user feel more competent in performing tasks and engaging in daily activities.

Adaptability: This domain assesses how well the user feels they can adjust to changes in their environment or lifestyle with the help of the device. It considers the extent to which the device enables users to adapt to new challenges and situations.

Self-Esteem: This domain focuses on the user's sense of self-worth and confidence as influenced by the assistive technology. It gauges whether the device helps improve or harm the user's perception of themselves.

PIADS contains 26 items, which are rated on a 7-point scale ranging from -3 (strong negative impact) to +3 (strong positive impact). The responses are designed to capture the user's feelings about the assistive device's influence on their psychosocial functioning.

This scoring system helps clinicians and researchers understand the degree to which an assistive device benefits or hinders a user's psychosocial well-being.

PIADS offers a comprehensive view of how assistive devices influence the psychological and social dimensions of users' lives, making it a valuable complement to tools like QUEST and the System Usability Scale (SUS).

2 Device Usability

Evaluation of Ease of Use, Comfort, and Functionality

The usability of the device is evaluated through a series of tests focusing on ease of use, comfort, and functionality. This ensures that the device is practical and effective in real-world settings.

Example: The wheelchair tray might be evaluated based on how easily it can be attached and detached, the comfort of using it for extended periods, and its ability to hold various items securely.

Usability Tests and Identification of Issues

Usability tests involve clients using the device in different scenarios to identify any usability issues or limitations. Feedback from these tests is used to make necessary adjustments and improvements.

Example: During usability tests, clients might use the tray at home, at work, and in public spaces to identify any difficulties or inconveniences. Issues such as instability on uneven surfaces might be identified and addressed.

SUS (System Usability Scale)

Erik and Cisa (1998) state that SUS is a widely used, quick, and reliable tool for measuring the usability of products, systems, or services. It consists of a 10-item questionnaire designed to assess a user's subjective experience with a system.

Key Features of the SUS:

- Quick and Efficient: The SUS is designed to be simple and fast to complete, taking about 1-2 minutes on average.
- 10 Questions: Users rate their agreement with 10 statements using a 5-point Likert scale ranging from "Strongly disagree" (1) to "Strongly agree" (5).
- Reliable: Despite its simplicity, the SUS is proven to provide reliable and valid results. It is effective in both large-scale and small usability studies.
- Subjective Usability: The SUS focuses on the subjective satisfaction of users, measuring their perception of usability rather than just task performance.
- Broad Applicability: It can be used to evaluate almost any system or product, from websites to consumer electronics to software.

Although the score is out of 100, SUS is not a percentage score but a relative measure of usability. Higher scores indicate better usability.

- 85 or above: Indicates excellent usability. The system is very user-friendly and intuitive.
- 68: Considered average usability. A score above 68 suggests above-average usability, while a score below 68 indicates usability problems.
- Below 50: Indicates poor usability. Users are likely frustrated or find the system difficult to use.

The SUS is often used in usability testing, product development, and research to gather user feedback, identify usability issues, and improve overall system design.

3 Improvement in Daily Activities

Measurement of Impact on Clients' Ability to Perform Daily Tasks

The primary goal of the assistive devices is to enhance clients' ability to perform daily tasks. Metrics are developed to measure the impact on tasks such as eating, working, mobility, and personal care.

Example: For the wheelchair tray, metrics might include the time taken to complete a meal independently or the frequency of use for work-related activities.

Analysis of Improvements in Mobility, Independence, and Quality of Life

The evaluation also considers broader impacts on clients' mobility, independence, and overall quality of life. Improvements in these areas are critical indicators of the device's effectiveness.

Example: The analysis might reveal that clients feel more independent and less reliant on caregivers for certain tasks, thereby enhancing their overall sense of autonomy and well-being.

COPM (Canadian Occupational Performance Measure)

COPM is a client-centered assessment tool widely used in rehabilitation and occupational therapy to evaluate an individual's performance and satisfaction in daily activities. It is particularly useful when assessing the impact of assistive technology on a person's life.

What sets COPM apart is its focus on the individual's perspective, allowing users to identify activities that are meaningful to them and where they experience difficulty or dissatisfaction. This personalized approach makes the COPM adaptable across a wide range of contexts, including self-care, productivity, and leisure.

The individual is asked to identify tasks across self-care, productivity, and leisure where they feel they are not performing well. Once these tasks are identified, the user rates the importance of each activity on a scale of 1 to 10, ensuring the focus is on areas that matter most. The user also rates their current performance and satisfaction with each activity, which provides a baseline for comparison later on.

The COPM is particularly useful in assessing a variety of assistive technologies, such as mobility aids (wheelchairs, walkers), communication devices, and home modifications like stairlifts or grab bars. It helps track how well these technologies improve the user's ability to perform daily tasks and engage in life activities.

By focusing on what matters most to the user, the COPM promotes greater satisfaction and long-term success with assistive devices

4 Engagement and Collaboration

Review of Stakeholder Participation and Collaboration Effectiveness

Successful co-design relies on active engagement and effective collaboration among all stakeholders. The evaluation includes a review of participation levels and the quality of collaboration throughout the process.

Example: The review might highlight the extent of clients' involvement in brainstorming sessions and prototype testing, as well as the contributions of occupational therapists and engineers.

Adaptability and Sustainability

Evaluation of the Device's Adaptability to Future Changes in Clients' Needs

Assistive devices must be adaptable to changing needs over time. The evaluation examines the device's flexibility and ability to be modified or upgraded as clients' requirements evolve.

Example: The wheelchair tray might be designed to accommodate different attachments or adjustments to cater to clients' changing needs, such as adding a cup holder or extending the tray's surface.

Assessment of the Device's Durability and Long-Term Use

Sustainability is assessed by evaluating the device's durability and its capacity for long-term use. This includes considering the materials used, the robustness of the design, and the ease of maintenance.

Example: The tray's durability might be tested through repeated use and exposure to different conditions to ensure it remains functional and reliable over time.

Conclusion

Conclusion

The co-design approach in developing assistive devices offers numerous benefits that significantly enhance the quality and functionality of the final products. By involving clients directly in the design process, the resulting devices are tailored to meet their specific needs and preferences, leading to higher user satisfaction and better usability. This participatory method ensures that the devices are practical and effective in real-world settings, as clients provide valuable insights and feedback throughout the development stages.

Additionally, the collaborative efforts of occupational therapists and engineers bring a multidisciplinary perspective to the design process, integrating ergonomic, technical, and aesthetic considerations into the final products. The iterative nature of co-design also allows for continuous improvements and refinements, ensuring that the devices are not only functional but also innovative and adaptive to changing needs.

Looking forward, the co-design approach has the potential to revolutionize the field of assistive technology. Expanding this framework to include a wider range of disabilities and assistive devices can broaden its impact and reach. Future directions may involve incorporating advanced manufacturing technologies such as CNC Machining, injection moulding and different 3D Printing techniques to further personalize and optimize device functionality.

Additionally, creating more robust and scalable platforms for stakeholder collaboration can enhance the efficiency and effectiveness of the co-design process.

The co-design framework exemplifies the importance of user-centered design in creating solutions that truly resonate with and support the users. As we continue to innovate and refine this approach, the potential to transform lives and foster greater inclusion and accessibility in society grows exponentially.

Ultimately, the success of personalized assistive devices underscores the importance of collaboration, empathy, and dedication in designing technologies that make a real difference in people's lives.

References

Aflatoony, L., and S.J. Lee. 2020. AT Makers: A Multidisciplinary Approach to Co-Designing Assistive Technologies by Co-Optimizing Expert Knowledge. *Proceedings of the 16th Participatory Design Conference 2020* 1(2): 1-6.

Aflatoony, L., S. J. Lee, and J. Sanford. 2021. Collective Making: Co-Designing 3D Printed Assistive Technologies with Occupational Therapists, Designers, and End-Users. *Assistive Technology* 33(4): 198-307.

Ankur J., K. Saket, S. Chandel, and D. K. Pal. 2015. Likert Scale: Explored and Explained. *British Journal of Applied Science & Technology* 7(4):396-40.

Cook A. M. and J. M. Polgar. 2015. Principles of Assistive Technology: Introducing the Human Activity Assistive Technology Model. In *Assistive Technologies* 4th ed., Cook A. M. and J. M. Polgar, 1-15. St. Louis, Missouri: Mosby Elsevier.

Day, S. J., and S. P. Riley. 2018. Utilising three-dimensional printing techniques when providing unique assistive devices: a case report. *Prosthetics and orthotics international* 42(1): 45-49.

Degerli Y., F. Dogu, and C. Oksuz. 2022. Manufacturing an assistive device with 3D printing technology - a case report. *Assist Technol.* 34(1):121-125.

Demers L., R. Weiss-Lambrou and S. Bernadette. 2002. The Quebec User Evaluation of Satisfaction with Assistive Technology (QUEST 2.0): An overview and recent progress. *Technology and Disability* 14: 101-105.

Doran G. T. 1981. There's a S.M.A.R.T. way to write management's goals and objectives. *Management review* 70(11):35.

Erik D. and V. Cisa. 1998. Questionnaire based usability testing. In *Conf. Proc. Eur. Softw. Qual. Week*, 1-9. Brussels. November.

Gherardini, F., M. Bordegoni, F. Ferrise, and S. Graziosi. 2020. A co-design method of additively manufactured assistive devices to reduce the impact of hand pathologies in daily living. *International Journal of Environmental Research and Public Health* 17(8): 2897.

Howard T. 2014. Journey mapping: a brief overview. Commun. *Des. Q. Rev* 2(3): 10–13.

Jutai, J. and H. Day. 2002. Psychosocial impact of assistive devices scale (PIADS). *Technology and Disability,* 14(3): 107-111.

McColl M.A., C.B. Denis, and K.L. Douglas. 2023. A Clinically Significant Difference on the COPM: A Review. *Canadian Journal of Occupational Therapy* 90(1):92-102

Moggridge B. 2006. *Designing Interactions* 2nd ed. The MIT Press.

Robinson, S., S. Hannuna, and O. Metatla. 2020. Not on any map: co-designing a meaningful bespoke technology with a child with profound learning difficulties. In *Proceedings of the Interaction Design and Children Conference*, 135-147.

Romani, A., and M. Levi. 2020. Parametric design for online user customization of 3D printed assistive technology for rheumatic diseases. In *Augmented Reality, Virtual Reality, and Computer Graphics: 7th International Conference*, 174-182. Lecce: Italy. September 7–10.

Sarmiento-Pelayo M.P. 2015. Co-design: A central approach to the inclusion of people with disabilities. *Rev. Fac. Med.* 63(1): 149-154.

Schwartz J. K., A. Fermin, K. Fine, N. Iglesias, D. Pivarnik, S. Struck, N. Varela, and W. E. Janes. 2020. Methodology and feasibility of a 3D printed assistive technology intervention. *Disabil Rehabil Assist Technol.* 15(2):141-147.

Slattery, P., A.K. Saeri, and P. Bragge. 2020. Research co-design in health: a rapid overview of reviews. *Health Research Policy and Systems* 18(17): 1-13.

Spencer D. 2009. *Card Sorting: Designing Usable Categories* 1st ed., Endsley K. Brooklyn, NY: Rosenfeld Media.

Thorsen, R., D. Cugnod, M. Ramella, R. M. Converti, and M. Ferrarin. 2024. From patient to maker - a workflow including people with cerebral palsy in co-creating assistive devices using 3D printing technologies. *Disability and Rehabilitation: Assistive Technology* 19(4): 1358-1368.