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Background

Inclusion and independence are essential for learning and facilitating a healthy environment. According to the UN Convention on the Rights of People with Disability, which emphasises independence for persons with disabilities, independence encompasses individual autonomy, persons being fully involved with decision making processes, and the opportunity to access the physical, social, economic and cultural environment ("Promoting Independence for People with Disability."). Owuor's protocol review emphasizes how assistive technology is a key part to providing inclusion for people with disabilities (2017). All students should feel empowered by their learning experience, and not have to worry about how they will be able to complete their work. When students with disabilities do not have workspaces that allow them to work comfortably, it detracts from their learning experience.

Our team, A-Tray, is a team that was created through HRS 2607 Introduction to Rehab Engineering Design and HRS 2718 Project Based Technology Design at the University of Pittsburgh. In this class we were assigned to attend programs at the Community Living & Support Services (CLASS).Through this experience we saw some users could greatly benefit from an adaptive, functional workspace. The user needs to be able to independently manipulate the product up and down, towards them, and angle the workspace. Devices similar to this already on the market have limited range of motion and are not user friendly to move and lock. User want to be more independent, but currently the instructors spend significant time setting up each individual workspace. Providing the user with more freedom helped them feel more involved and allowed the teacher to focus on other important aspects of the class. A-Tray has created a novel design that addresses the needs of multiple participants at CLASS and that can be expanded to many classrooms across the world.

Problem Statement

Individuals with limited fine motor skills at the CLASS center would benefit from workspace arrangements that promote inclusion in group activities and offer a range of adjustable positions to provide optimal configuration and independence for each user.

Research Question

The design was the result of observing activities for three specific wheelchair user types which we turned into three user personas: the active user, the close-up user and the tall user. Out of our six clients, two of them fell into the active user persona, two fell into the close-up user persona, and 2 fell into the tall user category. There was some cross-over primarily with the tall-user persona depending on the mobility device accessories users had on a given day (such as a wheelchair tray) or the table height they were using for a project.

The active users demonstrated varying degrees of muscular control and needed to stabilize items on their workspace to prevent uncontrollable arm or upper body movements that would otherwise disrupt their work or knock papers or tools off their work area. The position of their workspace also impacted their precision with drawing, gluing, writing or painting due to limited control of their hand/finger dexterity in certain positions. Most had an optimal position for motor control that often could not be matched with the available workspace systems available.

The close-up users showed limited range of motion (ROM) in their arms and head movements. Some users required instructors to reposition their paper or canvas multiple times in order to keep their work within their ROM. Others required repositioning so that they could see their work due to a fixed head position that made a flat work area not ideal for the field of vision.

The tall users showed challenges with reaching workspace. This was often a challenge because they had trouble pulling up to the standard work tables at CLASS, or because they had other attachments on their wheelchair such as AAC devices or trays. Many times these users were separated from other members of their class so they could use a taller table or they were left to use their wheelchair tray away from the table where their peers were working on projects. The user needs identified for this person were to create a system that allows for these users to remain in community with their peers while working on projects and that gives them access to using the standard tables at CLASS.

Approach

Design Criteria

At the beginning of our project, user needs were defined by observing classrooms and speaking with the users and instructors to learn what exactly they needed:

1. The device's stability can sustain uncontrolled movements by users (Force Testing).
2. The device controls writing surface for users (Clip Mechanism).
3. The device allows for positioning for workspace allowing user to have a direct line of sight and for optimal use of their motor function (Tray Positioning).
4. The device improves users range of motion for their workspace (User Range of Motion).
5. The device allows users to use adaptive workspace at the different types of table to allow for maximal peer interaction with different group activities (Versatility).
6. The device needs to be intuitive by users or instructors and take less than 2 minutes to set up (Set-up Time)
7. The device needs to be safe to use with no sharp edges, limited pinch points, and no chance of collapsing while in use (Safety).
8. The device needs to be under twenty pounds (Weight).
9. The device can not take up space on the workspace, or add depth to the device. It also should be minimally sized for storage. (Storage)

Prototype 1

The first version of the design was a rough prototype that contained a tray that we were able to change angles, but it was unable to move up and down and towards or away from the user. From this prototype, users reported they liked working on a slight angle. The size of the tray allowed for the users to reach all four corners of the workspace and placing a trough on the side of the tray was functional for all users. The users greatly benefitted from placing a lead on the tool the users were using. This allowed for independent retrieval of the tool if it was dropped.

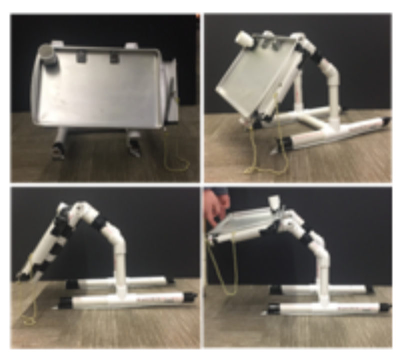


Figure 1: First prototype demonstrating angle motion.

Prototype 2

Prototype 2 demonstrated the mechanism that was visualized for the design. This was made out of small, light balsa wood. This prototype allowed us to show the users the way the tray could move up and down and they could pull it towards them. This prototype was small, so another prototype was made out of cardboard that was the correct size and also functional. The users enjoyed being able to see how adjustable the device would be and did not have any complaints about the design.

Figure 2: Prototype 2 to demonstrate mechanism.

Solidworks Design

From all of the prototypes, the dimensions that are most functional for the users were observed. The next step was to create the design on Solidworks to be able to figure out the movement of the joints and locking mechanism. This allowed for control of the weight of the device. The solidworks design showed the way the device would move, where the bolts and screws should be placed to keep it functional.

Concept Generation

In finalizing the design components there were key areas of considerations. One was in deciding the number of degrees of freedom needed so offer all our clients an optimally positioned workspace. Another was deciding on the mechanism to change the position of the tray that would be most intuitive and accessible to the users. Lastly, was how the device was attached to the table while ensuring stability and safety.

The design needed to move up, out, and change angles, therefore requiring three degrees of freedom. With that much movement, we had initial concern about stability of the unit. To ensure easier storage and provide users with more choice in positioning the system, we planned to add stability in other areas of the design.

It was important that the mechanism that extends the tray be intuitive to users and that it has a quick set up time for the system. We looked at using gas springs, but eliminated them due to their expense. We looked at using clevis pins or spring plungers with a telescoping system similar to how crutches adjust. However, this would limit adjustability because it would require specific interval options for the tray's positioning. We decided to use a mechanical system of a telescoping system and a hose clamp that locks the telescoping section in place. This allows users to pick any location along the range of positions possible and lock it in place for ideal function.

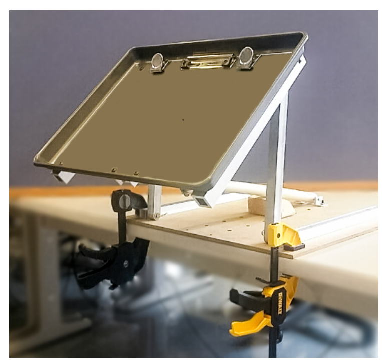


Figure 3: Final A-Tray Design

The system could not be a stand-alone unit on a table because of the forces applied to the tray, especially when fully extended. We had to determine a way to attach it to a table that would not damage the table, would not take a lot of time to set up, would be intuitive and would add stability to the system. We looked at using straps to the table, but this would be cumbersome for setup. We thought through using counterweight at the back of the unit, but this would make the unit heavier and larger than what would be functional. Ultimately, we decided on using clamps on the front of the unit. In testing this provided the needed stability without impacting the space needed on the table.

Concept Solution

Combining feedback on our various prototypes and different solutions we considered, we made our final design. This design contained a frame made of six aluminum bars. The bottom two bars were attached to MDF board to give more stability and allow for easy of attachment to the table. The device is attached to the table by placing clamps on either side. The device allows for three degrees of freedom. To adjust, the user needs to pull on the tray and adjust the device to their optimal work position for the task that needs to be completed. The device locks with a telescoping mechanism that allows for smooth movement and simple locking mechanisms that will not fall while device is being used, but allows for a complete collapse and easy storage.

Concept Testing

In each step, the six clients provided feedback about their experience using the A-Tray in comparison to the system they currently use to paint, collage, read, write or draw. Systems currently used ranged from an, A) Oversized clipboard positioned at an angle using, B) Cafeteria tray sitting on a drawer liner to reduce slippage, or C) Wooden angled tabletop easel. We also worked with three instructors to get feedback on the system and to find out how using it would change the dynamic of their classroom.

Table 1: Concept testing done to determine if product meets user needs.

User Need	Product Specs	Testing Method	Result
Force Testing ✓	Sustain similar or better forces than current systems when testing with door pressure Gauge.	Test force required to cause movement in workspace system. 1. Applied directly to tray 2. Applied to rear of tray 3. Applied to side of tray	See Chart 2 for force in pounds sustained by each system.
Clip Mechanism ✓	Have a better result than current systems used.	Observe and get subjective feedback from users	Top clip & magnetic clips on steel tray caused noticeable improvement for all.
Tray Positioning ✓	Previous research shows 10-20° can help increase line of sight on desk surfaces for people with physical disabilities (Shen 2003)	1. Get subjective feedback from users 2. Measure angle range possible with A-Tray	1. Users stated improvement and noticed benefit in neck positioning. 2. See Chart 3 for positioning options and user preferred positions.
User Range of Motion ✓	Will compare to ROM access with current system.	Ask users if they have more ROM using device than what they currently work with	All 6 users commented that they had better visual and physical access
Versatility ✓	A-Tray can attach to a range of tabletop depths	Measure range for clamping mechanism	Clamps for tables up to 2.25 inches thick.
Set-up Time	Device takes less than 2-minutes to set up by unfamiliar	Time instructors setting up the system with 5 step instructions.	Instructors took from 40-55 seconds for setup.

✔	users.		
Safety ✔	Simulate test for Sharp Edge Tester Model SET-50.	Run masking tape over all surfaces, joints, and edges to determine if any marks are left in the tape.	There are no sharp edges based on no markes to tape.
Weight ✔	Compare A-Tray's weight to other current devices; be under 50lb job description lifting requirement for CLASS staff	Weigh all systems for comparison	Wooden angled easel (6.8 lbs); Cafeteria tray (13.1oz); A-Tray (12.8lbs)
Storage ✔	System collapses flat for storage.	Observe if system can collapse onto itself with minimal footprint for storage purposes/stacking.	Yes, collapses on self 2in depth

Chart 2:

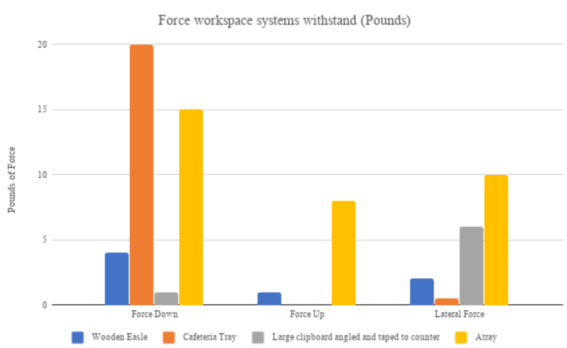
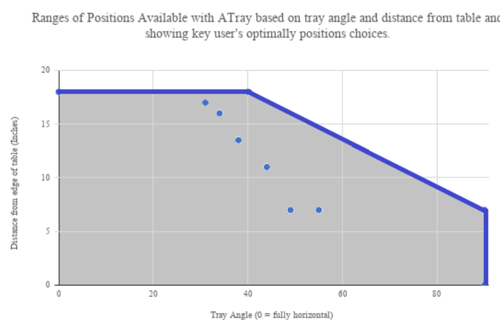


Chart 3:



User Feedback

The two user needs where A-Tray got the most positive response from users was in papers being stabilized and in the workspace and being positioned so that users could see and reach their workspace more easily.

Beyond meeting the user needs outlined above, using A-Tray changed users posture When using a table or wheelchair tray, the users had a flexed neck position. With A-Tray users could look directly forward reducing the need for a kyphotic position. This not only meets a need to improves the health of users. (De Wall 1991).

The teachers we interviewed on our final prototype stressed how challenging it is to include all participants at one table because everyone is at a different height and require some assistance. Relying less on the instructors to adjust their work during projects would give users more autonomy in completing their projects. The importance of facilitating inclusion and actively creating opportunities for people with intellectual disabilities using assistive technology is outlined in Owuor's protocol review (2017) and in Robinson's study (2018).

Cost

The table below details the raw material cost required in order to manufacture a single unit of the A-Tray product, which totals to a value of $73.15. A market standard product used in comparison to the A-Tray product was an adjustable laptop tray stand. Such products are available in the industry for an average of $75.00. Our product would be valued higher due to additional adaptability and customizable features unlike any other products currently available in the market. However, the cost of production can be driven down by streamlining the manufacturing costs and cost effective material selection in future development. The ultimate market introduction price would take into consideration large scale manufacturing, labor costs, and additional production costs associated that are not included in this raw material evaluation.

Table 2: Raw material cost for a single A-Tray unit

Quantity	Item Description	Unit Price	Subtotal Price
4 feet	3/4"-3/4" Aluminum Solid Bar Stock	$4.18	$16.72
2 feet	1"-1" Aluminum Rectangle Hollow Tube Stock	$6.86	$13.72
2	1/4" x 1 3/8" Steel Clevis Pin	$1.10	$2.20
4	1/4" x 1 9/16" Steel Clevis Pin	$1.20	$4.80
6	W.D. 3/64" E.D. 1/4" Cotter Pins	$0.32	$1.92
20	1/4" Brass Washer	$0.09	$1.80
4	1/4" Nylon Unthreaded Spacer	$0.09	$0.36
2	Ratcheting Bar Clamp	$2.99	$5.98
1	Steel Tray Top	$10.99	$10.99
1	Medium Density Fiberboard 1/4x2x2’	$3.72	$3.72
1	½”-1” Hose Clamp	$1.20	$1.20
4	L-Brackets	$1.00	$4.00
10	24 x ½” Screws	$0.43	$4.30
1	Clipboard Clip	$1.44	$1.44
1	2” Wood Block	$0.31	$0.31
2	¾” Wood Screws	$0.20	$0.40
		Total =	**$73.15**

Significance

The device has provided invaluable independence to the users. They are able to adjust the angle based on what is more comfortable for them to complete the goal of the class and use the clip to keep papers from moving. From observation, the device also improves user posture. A-Tray users who are used to being in a kyphotic position when working at the table will see great long term benefits. The use of the tray limits back pain and improves overall posture of the user. The design has cut down set up time for the teacher, so they are able to spend more time giving instruction during class. The teacher also has limited clean up and is able to easily collapse the workspace and store it with taking up minimal space. This device has had a significant benefit on the users to help them complete many tasks with more independence and has saved the teachers time and effort during class.

Acknowledgements
In no particular order:
Dr. Jonathan Pearlman - Instructor
Dr. Mary Goldberg - Instructor
Dr. Garrett Grindle - Instructor
Joseph Ott – Teaching Assistant
Community Living and Support Services
University of Pittsburgh - Swanson School of Engineering
University of Pittsburgh – School of Health and Rehabilitation Science
Human Engineering Research Laboratories

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