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Assistive Technology Makerspaces Promote Capability of Adults with Intellectual and Developmental Disabilities

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Abstract: Makerspaces can engage people with disabilities in the design and development of assistive technology (AT) that can enhance their capabilities to perform new activities and function. However, the adoption of makerspaces in the environments and institutions serving people with disabilities remains challenging. The authors modeled a makerspace training program, an environmental intervention, based on the capability approach framework. This mixed methods study investigates the feasibility of an 8-week program to train adults (n = 5) with intellectual and developmental disabilities (IDD) and staff members (n = 5) at a community services center. Study outcomes were measured using knowledge tests, surveys, QUEST 2.0 and interviews. Results indicate a significant increase in staff's knowledge (p = 0.035) and familiarity with program topics ($p < 0.05$). Participants with IDD were highly satisfied with the ease of use, weight and effectiveness of the AT devices they created. Five themes emerged from the thematic analysis of interviews: (1) inclusive environment, (2) freedom and improved *Capability* for building technology for self or client, (3) multidisciplinary collaboration, (4) interactive program elements, (5) makerspace challenges. Overall, the makerspace training program is a valuable program that empowers people with disabilities and ensures the realization of their right of autonomy to create their own AT.

Keywords: 3D printing; assistive technology; capabilities approach; developmental disability; inclusion; intellectual disability; makerspace

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1. Introduction

The prevalence of intellectual and developmental disabilities (IDD) in the United States ranges from 1.10 to 4.84% [1]. Adults with IDD may not demonstrate the same level of intellectual functioning and adaptive behavior, including conceptual skills, social skills, and practical skills as adults without IDD [2]. Such a difference results in reduced involvement during activities of daily living (ADLs) and leads to dependence on family members, caregivers and/or healthcare institutions [3]. Hence, the majority of individuals with IDD cannot enjoy freedom and participate fully in society, which is essential for a good quality of life.

Assistive technology (AT) is a generic term used to describe systems and a range of products that support functioning [4]. AT is integral to the functioning and freedom of individuals with IDD. One can leverage the features of safe, effective and affordable AT to enhance capability in performing activities, including recreation, self-care and vocational activities [5]. AT devices such as canes, wheelchairs, augmentative communication devices, hearing aids, and toileting aids are often available through clinical prescription. Some of the highest rated AT used to support people with IDD include low-tech devices and high-tech devices. Low-tech AT includes divider plates, built-up handle eating utensils, and pencil grip. High-tech devices are wheelchairs, walkers, ramps, grab bars, accessible computer software, electronic organizers, hearing aids, audio books, speech-generation devices, picture prompts, memory aides, smartphones, recognition by digital technologies, screen reader, automatic page turner, and closed captioning [6]. Individuals with IDD utilize technology in various settings, including their workplace or daily life, to improve their ADL task performance [7]. While AT devices increase freedom in performing ADLs and other areas, custom AT devices may not be available for prescription or commercially. Such custom devices have appropriate features configured to the individual's internal resources (strength, range of motion, specific body part dimensions, etc.) and external resources (environment of use, caregiver use) which maximizes one's capability. Such custom AT devices need to be designed and developed.

The design of custom AT has happened through myriad approaches in collaboration with people with disabilities. Conceptual models like the HAAT and PHAATE [8] provide considerations for AT design and selection requirements. Other approaches in higher education include peer-induced competitions or peer review and interdisciplinary team approaches. To ensure people with disabilities are central to the design process and can access tools and instruments, environmental modifications have been performed [9]. Three-dimensional (3D) printing technology, excessively used for creating custom low-tech devices, has been used in academia, the medical field, and the engineering industry [10,11]. These models, approaches and techniques have been implemented in diverse institutional settings or workplaces but are unable to serve as a resource or commodity for the majority of people with disabilities that enhance a person's capability.

Firstly, in most approaches, people with IDD take on a consulting role for testing and validating AT rather than actively developing the AT. This negates full realization of individual capabilities. Secondly, these interventions have occurred in environments not frequented by people with disabilities. This highlights the lack of appropriate resources such as healthcare and institutional policy around access for people with disabilities. Thirdly, current approaches are not aimed at educating or training the person with support from external resources, i.e., stakeholders and caregivers for an individual with IDD. Thus, existing approaches are lacking in provision of custom AT as well as keeping the individual with IDD reserved from realizing their full capability for developing the custom AT they need and the choice of using it for improved functioning.

There is a clear need for developing environmental interventions (EI) that enable people with IDD to exercise their access rights and autonomy to develop the AT for full participation and freedom [12–14]. A relatively new concept that can enable access to AT design and development is a makerspace [14]. Recently launched in some public libraries or schools, a makerspace is a workshop where a wide variety of tools, materials, and technologies can be found for making new products. A makerspace also serves as a collaborative meeting place for people interested in low-cost and custom-built devices. Owing to the benefits of a makerspace as an environmental intervention, the authors established such a facility at the Community Living and Support Services (CLASS) center in Swissvale, Pittsburgh, Pennsylvania. The makerspace accommodated a desktop 3D printer, everyday use materials for prototyping and educational resources for using the makerspace facility. This study aimed to develop and pilot test the efficacy of a training program with people with IDD and center staff through participatory action research based on the capability approach.

2. Materials and Methods

2.1. Theoretical Framework

The capability approach [15–17] was adopted as a theoretical framework to guide the design of the training program. Adopting the framework ensured that the unique everyday experiences of people with IDD were captured and integrated into the program.

While limitations of people with disabilities are well realized, the capabilities approach substitutes limitations with capabilities or functioning at the individual, societal and environmental levels [18]. The capability approach includes three constructs–*Resources*, *Capabilities* and *Functionings*. Per the work published by Verd and Andreu, the three constructs are connected as shown in Figure 1 [19]. *Resources* refers to a set of rights and commodities available to an individual depending on their context. For instance, public policies and healthcare plans affect the resources assigned to an individual with disability. *Capabilities* on a personal level are realized by being or doing what one can as per their skills, talents, physical condition and sex. *Functionings* entail a set of actions that an individual carries out based on *Capabilities*. *Conversion factors* include personal characteristics and/or individuals in the society and EI that may limit or enhance the conversion of *Resources* to *Capabilities*. *Choices* may limit or promote the transformation of *Capabilities* (or provide options a person has at hand) to *Functionings*. The capabilities approach allows us to estimate and bridge the gap between individual capabilities and societal opportunities thus, maintaining the access, health and rights of people with disabilities.

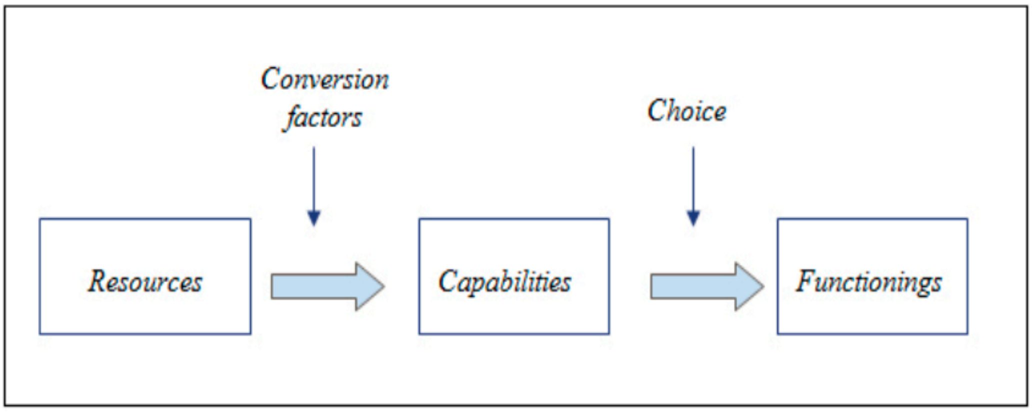

Figure 1. Capability approach adapted from Verd and Andreu [19].

2.2. Study Participants

The Director of Residential and Educational Programs at CLASS assisted in recruiting participants for the study. Study participants were recruited if they had a prior assessment of mild-moderate intellectual disability and were currently enrolled in the skills-building program. Study information was provided for the participants and their caregivers and consent was obtained to participate in the study. Staff were recruited from CLASS following informed consent. Ethics approval for conducting the human subjects' study was obtained from the Duquesne University Institutional Review Board in June 2021.

2.3. Development of Makerspace and Training Program

The author AB conducted assessments of Resources for and Capabilities of adults with IDD at CLASS and the Capabilities of the CLASS personnel. Based on the assessments, an accessible makerspace facility was established for staff and people with IDD at CLASS. The facility included a 3D printer, hand tools, everyday use materials, posters and manuals for printing and designing AT, and a suitable space for prototyping. Figure 2 shows the makerspace's 3D printing facility. The assessments further directed the design of the makerspace training program.

Figure 2. 3D printer from MakerBot [20], printing materials and other educational materials (the photo is taken by the authors).

The author AM is an instructor of assistive technology and medical device design courses for undergraduate and graduate students at the health and engineering schools of a university. Clients with disabilities and stakeholders partake in these courses as consultants for developing appropriate AT devices for use in community and clinical settings. By brainstorming with author AB and the Director of Residential and Educational Programs, topics from the program essential for building AT with cohorts of people with IDD, their caregivers and CLASS staff were selected. Each topic content was discussed for (1) simplification of content for teaching to and learning for a non-technical person, and (2) flexibility in the learning process. In addition, we ensured that environmental or structural factors or CLASS's instruction practices do not limit learning and the conversion of *Resources* to *Capabilities*.

Groups were formed with a person with IDD, a CLASS staff member and an undergraduate or graduate university student who provided technical and design assistance to the group. Caregivers occasionally participated in the workshops or classes. Four workshops in the program focused on: (1) needs assessment (2) CAD workshop, (3) 3D printing demonstration and makerspace education, and (4) building AT using everyday materials. Proceedings within these workshops included lectures, videos, diagrams, hands-on training, demonstrations, and discussions.

In the needs assessment workshop, a semi-structured interview guide was used to identify the needs of the participants. Solutions were generated based on needs, drafted on paper, discussed within the group. During the CAD workshop, groups were educated on how to use Tinkercad, a free online CAD software [21]. Staff with support from the students followed along with the instructor, using their laptops to design a 3D model house. During the 3D printing workshop, the Makerbot Sketch 3D printer was demoed, and participants learned about using stepwise 3D printing of their CAD models. Lastly, the fourth workshop introduced groups to everyday materials such as industrial twist ties, Model Magic, Velcro, and corrugated plastic to create low-tech AT devices.

Homework assignments can help deepen the understanding of concepts and build essential skills while evaluating the improvement in *Capability*. After each workshop, a worksheet or online assignment was completed by each staff member. They had two weeks to complete them. The idea of these assignments was to provide staff with another opportunity to rehearse and apply skills and concepts learned from the workshops. The online assignments were created using Qualtrics and contained multiple choice and short answer questions. One of the worksheets involved staff using Tinkercad and creating a pencil holder using step-by-step directions in the assignment guide. Five fundamental homework characteristics proposed by Vatterott (2010) [18] were included in each assignment to ensure these assignments were not rote learning. Further, the assignments required staff to reflect on what they learned.

The third component of the program was bi-weekly individual meetings with staff. These meetings were essentially office hours that focused on providing staff with individual assistance/discussions, responding to questions from the workshops, assignment clarification, and individualized learning of the material especially, technical topics like CAD and 3D printing. To make staff more familiar with such topics, staff were trained further on the 3D printing software, using the printer features of filament change and object removal, and lastly, printing a leisure object of their choice.

The last component of the program was weekly classes tailored to participants with IDD. These classes further strengthened the learning of concepts presented in the workshops. There was a total of eight classes which allowed more time for interacting and learning workshop material and more specialized interventions and support. Depending on the *Capabilities* of the individual and *Choice* to execute the *Functioning* of learning, teaching interventions and technology instruction were pursued. Teaching interventions included drawing pictures and visuals, tactile aides, interactive activities, and group discussions. Technology instruction included using YouTube videos, PowerPoint slide decks, and mobile learning with an iPad, and Kahoot.

At the end of the program, groups created 3D printed AT for the person with IDD in the group. *Functionings* with the new AT were observed with the clients in CLASS settings.

2.4. Pilot Testing the Efficacy of the Program

To evaluate the 8-week makerspace training process and outcomes, a mixed methods single group pre-test/post-test study design was utilized. Quantitative data on demographics, satisfaction, knowledge, experiences and perceptions of the training were collected through validated tools and custom surveys. Qualitative data were collected through Interviews conducted after the program to assess participant's and staff's program experiences. All assessments were completed on paper. Conceptually, these evaluations assessed the improvement in *Capabilities* and *Functionings*.

2.4.1. Demographic Survey

Demographic information about participants with IDD's gender, age, race, residence, employment, level of IDD, and primary diagnosis was gathered from their Individual Service Plans (ISP) prior to program implementation. A nine-item demographic survey was used to collect information on staff before the start of the program. Staff demographic information included gender, age, race, socioeconomic status, education, employment status, years employed at CLASS, and number of years worked with individuals with disabilities.

2.4.2. Knowledge Test and Knowledge Survey

A five-item multiple-choice knowledge test (Appendix A) was administered to staff before and after the program to assess their knowledge on 3D printing, CAD, and makerspaces. An eight-item knowledge survey (Appendix B) was administered before and after the training program. Staff rated their degree of familiarity regarding makerspaces, 3D printing, computer-aided drafting (CAD), addressing client needs, the design process, AT, and general technology using a four-point Likert scale.

2.4.3. Satisfaction Evaluation

The QUEST 2.0 was used to evaluate staff and participant satisfaction with their 3D printed device. This free instrument includes twelve items rated on a 5-point satisfaction scale from not important to very important [22]. The QUEST 2.0 has high test–retest reliability and internal consistency. To assist with comprehension, the researcher verbally read questions to the individual with IDD, explained selection options to ensure understanding and decrease stress, placed each question on separate sheets of paper, and used visual thumbs up and thumbs down icons to represent the scale.

A staff satisfaction survey (Appendix C) was used after the program to assess staff's satisfaction with the objectives and content, methods and training content, and usefulness and overall rating. The staff satisfaction survey consisted of 21 items requiring staff to rate each question on a four-point Likert scale from strongly agree to strongly disagree. This staff satisfaction survey was based on a 12-item training satisfaction rating scale used in a similar study, which had good content validity [23].

2.4.4. Semi-Structured Interviews

Study participants were interviewed after the program. Two separate semi-structured interview guides were used for participants with IDD (Appendix D) and staff (Appendix E). The ten-question staff interview guide asked staff about their experience collaborating with the participant, the most and least beneficial parts of the program, their confidence/skills, and beliefs about the training program and makerspace. The participant interview guide was created based on the staff interview questions and included questions related to the technology class. Plain language was utilized to ensure individuals with IDD understood the questions. All participants were allowed to speak for as long as needed to answer the questions fully. Interviews were completed in a private, quiet classroom or conference room and audio-recorded.

2.5. Data Analysis

All responses on the study instruments were de-identified prior to data analysis. Participant demographics were analyzed using descriptive statistics. Standard deviations and means were calculated for continuous data (age, years employed, total knowledge test scores and QUEST 2.0 scores). Ordinal data, including Likert scale data from the QUEST 2.0 and satisfaction survey, was analyzed using descriptive statistics. A paired t-test was used to analyze the total mean pre-test and post-test scores on the knowledge multiple choice test. SPSS 27.0 was used to analyze quantitative data.

Interviews were audio recorded and transcribed verbatim to ensure accurate interpretation of qualitative data. Transcripts were de-identified by removing names and identifying characteristics of persons and facilities. Additionally, during the interview, the researcher repeated what the interviewee said to ensure understanding and acquire the most accurate and valid results. A systematic approach to qualitative thematic analysis was used to analyze interview data and identify and develop codes and themes using NVivo 12 Plus. First, all interviews were read by two independent researchers to gain an overview of the content. Next, the interviews were inductively coded, and the codes generated were shared and discussed among the co-authors. Following the discussion, themes emerged that highlighted the strengths and weaknesses of the program.

3. Results

3.1. Study Participant Characteristics

Five groups participated in the 8-week training program. Tables 1 and 2 show the demographic characteristics of the study participants with IDD and staff, respectively. All participants and staff identified White or Caucasian as their race. The participants experienced moderate intellectual disability with a variety of developmental disabilities. They used a wheelchair as a primary device for mobility.

Table 1. Demographic characteristics of participants.

Characteristics	Participants with IDD (n = 5)
Age	38.4 ± 16.8 years
Gender	3 females, 2 males
Type of Residence	
Family/Guardian	3
Residential program/Supported living	2
Primary Diagnosis	
Cerebral palsy	3
Traumatic Brain Injury	1
Poliomyelitis	1

Table 2. Demographic characteristics of staff.

Characteristics	Staff (n = 5)
Age	40.4 ± 14.2 years
Gender	5 females
Full-time employment tenure	17.4 ± 14.6 years
Experience working with individuals with disabilities	18.0 ± 13.9 years
Income	
USD 15,000–USD 34,999	3
USD 35,000–USD 49,999	1
USD 50,000–USD 74,999	1
Education	
Bachelor's degree	4
Master's degree	1

During the workshops, a key chain, pen and paintbrush holders and stands for phones and playing cards were developed for demonstration and use. The prototypes are shown in Figure 3. CAD model houses and rings were designed using Tinkercad following the CAD workshop. At the end of the program, two groups created devices for leisure and play using 3D printing. One was a guitar pick, the other a tug of war AT to play with dogs. The participants used the devices to engage in meaningful activities following the program's conclusion. Two groups developed AT for their daily use. A cup holder for a coffee cup that can attach to a wheelchair was designed. Additionally, a can holder device that attaches to the soda vending machine was built. Both ATs (see Figure 4) were installed and tested. The cup holder worked well for holding a coffee cup; however, the can holder required a design revision to enable the participant to pick up the soda can by themselves. One participant required modification to the wheelchair joystick, which could not be completed during the program. This person adopted AT built for demonstration for their use during skills-building classes or rather *Capabilities*-building classes.

Figure 3. AT prototypes built for demonstration.

Figure 4. AT built for daily use.

3.2. Knowledge Testing Results

Both the staff knowledge test and survey showed a significant increase in the mean test scores from pre-test to post-test ($p < 0.05$). Staff also felt more familiar with program topics after the program than before ($p < 0.001$).

3.3. Satsifaction Evaulation with Designed at and Program

Out of 5, the QUEST device subscale scores were 4.7 $\pm$ 0.38, services subscale scores were 4.8 $\pm$ 0.42 and total scores were 4.7 $\pm$ 0.35, indicating high satisfaction with the 3D printed devices. Of all the QUEST items, the top three most important were ease of use, weight, and effectiveness.

The staff rated the program out of 4: Objectives and overall content scores = 3.67 $\pm$ 0.6, method and training content scores = 3.55 $\pm$ 0.52, and usefulness scores = 3.6 $\pm$ 0.48.

3.4. Interview Results

Five overarching themes were identified: (1) inclusive environment, (2) building 3D printed AT devices for self or client, (3) collaboration between participants, staff, and universities, (4) interactive program elements, (5) challenges for future makerspaces and training programs. Comments from participants and staff are labeled from P1–5 and S1–5, respectively.

3.4.1. Theme 1: Inclusive Environment

This theme focuses on the open environment created by the program that enabled staff and participants to feel included and comfortable sharing of creative ideas.

Participants enjoyed building AT in the supportive training environment.

[Would you say Tinkercad was hard, easy or in the middle?]—"Easy" [Okay, any reason for why you liked it or why it was easy?]—"Fun" —P1

[Can you tell me what the best part of the training program was?]—"Just having fun " —P2

"I wish it wasn't over" —P5

Staff participant stated a benefit of the program:

"I think it was cool and creative and fun and I'm like it's exciting to see participants be excited about stuff and like have something to look forward too." —S5

"I guess just having people (with IDD be) more confident and sharing ideas . . . might give them the thought to do, to share when it normally wouldn't happen . . . " —S2

" . . . as long as it's in like a space that's accessible to everyone, I think hopefully people will be comfortable working with it." —S5

Another staff participant stated the importance of ensuring that the program participants feel included, accepted, and heard throughout the process.

"It's the more we engage them and the more they feel involved, the better the projects can be, and you know they're going to feel like they matter which they do, of course, and um they're going to feel included, and a lot of the disability community doesn't really feel included. A lot of people come into their lives and takeover situations or (make) decision for them, so they don't really know sometimes how to differentiate between the two and they feel they can't be independent and speak up for themselves and this is a perfect situation where that can be, so the more you can interact with them the better." —S3

3.4.2. Theme 2: Freedom and Improved Capability for Building Technology for Self or Client

This theme's concept embodies addressing a need through learning, creating, and building an AT device for oneself or for a client. Terms related to individual freedom and capability of building AT devices were included in this theme. When asked about the program's most and least beneficial part, everyone stated there was no "least beneficial" part.

In response to what they liked about workshops, participants stated:

" . . . we could make a cupholder, and a keychain and that." —P4

When asked why they like 3D printing one participant responded:

"Because you get to 3D print what you want." —P3

"I think it could be great for (the participant) like I said, adaptive equipment or anything they needed. It was beneficial because we got her (P3 participant), we built, what she wanted." —S3

" . . . At home, a lot of these guys have their nurses or attending care people there to help them or their families and that you know everyone is going to help them do whatever they need, but then if someone moves out into the community and lives by themselves or in a group home or apartment with somebody else they may need some more things . . . those (are the) kind of people that want to be on their own at some point and seeing what kind of stuff we could make." —S4

"(P1), his little cup holder was so simple, but he just loves riding around with his little coffee cup in there . . . it's just the knowledge of knowing there might be something out there that you're able to create to help someone." —S1

Another staff member talked about creating AT devices that increase an individual's freedom specifically in the skills building program:

[How would you apply what you learned during the training program to a real-life scenario?]—"I think it can be super helpful in classes like arts where people would need one on one support that you can't necessarily provide in a class of 6 people and one instructor. I think that it's going to be easier to figure out what people's specific needs are, and then have those needs met with some sort of material or device rather than the instructor getting up and running around and trying to be like "let me help you with this and this and this" . . . then that (the device) also gives the participants a better sense of independence." —S5

Having individuals with IDD choose the AT of their *Choice* allowed the customization of the device to client needs and sustainable use. One staff member noted that with a specialized and individualized device, the client may be more inclined to use the device and benefit from it in their everyday life:

"I think it's going to benefit her, and I know art is something she really loves, so it's not going to like sit on a shelf it's actually something that's going to be used. You know you don't want to build something that is just going to sit on a shelf for decoration or they're going to put it away and then forget about it . . . The thing you built for [participant name] with his coffee cup is very beneficial. It's every day, this is something that [participant name] is going to use every time she is in art (class)." —S3

3.4.3. Theme 3: Multidisciplinary Collaboration

Healthy collaboration between participants, their caregiver, staff, university students, and program personnel was crucial to the training program. It enabled creating AT devices that met the staff's criteria and client's needs. Staff participants reported multidisciplinary collaboration as beneficial because it produced useful AT. Staff and caregiver's familiarity with the participants was a key element for needs assessment.

One staff member (S4) stated that this collaboration was most effective when a participant had been attending the skills-building program for a longer period of time, as staff knew these participants better and could developed better ideas for a device compared to participants that had just joined the program.

Understanding new participants and their wants and needs was difficult in one case.

"And the stuff with [another participant], we don't know him that well. He is relatively new here, so we're still learning what he's like and things that he likes." —S4

Participants also enjoyed working with staff and stated that the collaboration was helpful and easy.

Two staff highlighted the collaboration with universities and how this is important for creating the devices as well as sustaining the makerspace.

"Well, I'm hoping collaboration with the universities maybe other students that I'm working with who have an interest in AT would be willing to do something in that vein . . . that possibly someone on staff could be more familiar and want to do some things with it." —S1

"And working with those guys (students) to help us to do something for some of the folks here like with what we're doing with [name]. Having something like what [name] wants to do with the (vending machine) extender." —S4

3.4.4. Theme 4: Interactive Program Elements

The fourth overall theme identified relates to the program's interactive elements, including hands-on learning, demonstrations, physical AT or leisure devices, and visuals.

Participants liked how using the everyday materials was interactive as well:

[What was the best part of the program?]—"Playing with new devices." —P1

Another participant described how he created the one-handed cardholder demonstrating the impact that this interactive piece had:

"Remember I put it on there" [I know you did awesome you made an extra one did you know that?]—"Yeah" [You made two cardholders.]—"I umm I put blue (tape) on first one and I put it on there (the black corrugated plastic) remember?" —P4

Staff appreciated the third workshop where the 3D printer was demoed, physically printing a small house:

"I think the most beneficial was the hands on and the visuals, being able to see the actual printer being able to see the process of how things are made and just even understanding the definition of what is a makerspace . . . I'm sorry it would have just been difficult if we didn't have a 3D printer and you were just talking to us about that." —S1

"And when [instructor name] demonstrated the machine, I think it was the third training before it even worked and before we even did anything, and he showed us all the parts and opened it up and it was cool because you could see it from the side and just straight on." —S3

[Which workshop was your favorite the 3D printer or tinker CAD?] "Printer" —P4

Using demonstrations during workshops, classes, and meetings assisted participants with learning the material:

"[What was beneficial during the training program?]–"The one-on-one meetings that we had just like having someone kind of do the process in front of me always helps just seeing someone go through it themselves first and then I can kind of like do it after a demonstration." —S5

Additionally, demonstrating the process of 3D printing over the course of the 8-week program assisted the groups in realizing the time it takes to create a 3D printed object. S5 stated:

" . . . seeing the 3D printer like in action was helpful and recognize how like long of a process that is, and I think that was good for the participants to see as well so they're not just like thinking that they can just like come up with an idea and it's just like boom right there in front of them like they understand it's a process that needs to take time."

Additionally, 3D printing being a physical process, helped engage participants in hands-on learning of physically producing a tangible product. Staff referenced the physical leisure object that they produced during their last meeting:

"Well, it's really nice not just sitting in the classroom or reading through something, someone doing something tangible, leaving with products [name] got her elephant (points to person) [name] got her snake." —S1

[What was beneficial regarding the training program?]—"To have a product for somebody or myself like when we did the demonstration of the thing that I printed out, the elephant, and I got to sit and watch it print." —S3

Staff additionally referenced the last workshop's demonstration with the everyday materials as beneficial and engaging.

"Some of the stuff you showed us the demonstration stuff that you brought in." [Yeah, like all the bendy twisty ties and materials?]—"Yes, I knew about the one that screwed on the table, because I've seen that before for other things, but I didn't know that was the material it was made out of." —S3

3.4.5. Theme 5: Makerspace Program Challenges

The four main challenges that emerged include individuality, interest, technical jargon, and time. One challenge brought up by staff was the need for the program to be more individualized for each client. Since the program was only 8 weeks long, time was a factor in limiting the interaction time between group members. Although limited individualized AT devices were created, they could be even more specialized to the participant with more time getting to know their needs and understanding of internal and external resources.

"Picking somebody and making it (AT) more individualized for their need; if they need something printed and getting to know them a little bit rather than just in a group and class (would be helpful)" —S5

Additionally, staff valued choosing program participants that actually need something, not just those that meet the inclusion criteria. Some participants will want to participate since they know they are receiving something; others may not be interested. Therefore, it is important that the participants are interested, enthusiastic and invested in this process.

"You don't want to work with someone who gets bored very easily, you want to make sure they're engaged and interested in what you want to do, so that's why you want to ask them first. If we build this for you and collaborate with them, how would this be beneficial and get feedback from other people who know her or know people better until you get to know them better." —S3

Another barrier was the technical jargon of 3D printing vocabulary. Some of the staff suggested:

> *" . . . keep the project simplified, don't make it complicated for them, and don't use technical jargon . . . break it down to language"* —S3

> *" . . . maybe like some terminology that she (participant) may not understand as much"* —S2

Additionally, one staff member suggested that the training program for building AT should be allotted more time.

> *"Maybe a longer, more time being focused on the actual Tinkercad, because while we understand the concept and we were able to, with your assistance, print out something, we're pretty clearly not at a stage where we're going to develop something."* —S1

Staff showed a positive outlook to the future of the makerspace facility.

> *" . . . maybe every now and then you know if a client presents an idea or something like just to go in there (the makerspace) and sit with them, and kind of you know, talk about it . . . "* —S2

A contrasting opining regarding 3D printing devices was mentioned by a staff member who felt the technology was beneficial but did not feel she was going to use 3D printing.

> *"In fact, for me I love the technology and I love the idea of it, but smarter minds than mine will understand it and when it comes out, I'm like "that's really cool" and I don't care how it's made (laughs) . . . just having something that would help these guys be a little bit more independent in their lives. That's all we all care about is getting these guys a little more independent and if that helps, fantastic."* —S4

4. Discussion

Our study highlights the importance of inclusion and demonstrates that people with disabilities can be included in the design of their AT. Contrarily, an existential inequity is people with disabilities are left behind in the decision-making process for disability programming and policies [24]. The majority of existing practices are based on the medical model of care. The capability approach advocates a different model; it moves the focus from disability to *Capability*. *Resources* can be amplified or converted by an EI (*Conversion Factor*) to enhance the *Capabilities* of an individual.

This study leveraged the capability approach to develop and test a new EI for the CLASS community–a makerspace training program. The program outcomes demonstrated that an appropriate EI (*Conversion Factor*) catalyzes existing set of internal *Resources* (wants and needs of individuals with IDD) and external *Resources* (CLASS staff, caregiver support, makerspace) to enhance the technology building *Capabilities* of an individual with IDD. As a result, people with IDD now have the *Choice* to choose from a variety of AT at CLASS and use the AT for new or improved *Functionings,* including AT for *Capabilities*-building program courses, playing and performing daily activities at CLASS.

Building an appropriate EI is key for successful programming. Assessment of *Resources* and *Capabilities* allowed the authors to understand the people and practices at CLASS. This knowledge assisted with creating the workshops, classes and other proceedings in the program. Flexible and individualized learning and support from the program instructors were strategies adopted in the program. Representation of multidisciplinary expertise in the group is a must for AT design. This groundwork conducted to inform development and deployment of the EI proved crucial for generating successful program outcomes. Study participants expressed greater satisfaction with the AT they built and highly rated the usability of the devices. Most of the AT devices were adopted by individuals with IDD, thus empowering them with a *Choice* to engage with their environment at a higher level of *Functioning*.

The makerspace in CLASS's facility is a novel *Resource* addition for the CLASS community and staff. It further increases CLASS's *Capability* as an institution to engage meaningfully with individuals with IDD so that individuals can enjoy freedom in the environment with a new makerspace. The program significantly increased the staff's knowledge of designing AT using makerspace and led to building satisfactory and usable AT. The staff can utilize the knowledge and the makerspace facility to create new AT for use by students with IDD in the courses such as crafts, gardening, communication and cooking. This outcome potentially reduces the burden on the staff. The staff rated the program very highly as it duly expanded the combined set of individual and staff *Capabilities* in CLASS's ecosystem.

While piloting the program was effective for individuals with IDD and CLASS staff, the interviews highlighted the program's value. An inclusive environment allowed individuals with IDD and staff to wholeheartedly enjoy the AT design experience. Individuals and staff were active stakeholders in the teaching-learning process compared to design programs where individuals act in a consulting role and are not afforded the freedom to learn or educate themselves. The theme of freedom and improved *Capability* to build AT demonstrated that people took ownership of creating AT and exercised their right of autonomy to create one. In the same vein, one staff pointed out that people around individuals with IDD make decisions for them, while the program demonstrated that individuals have the freedom and *Choice* to build their own AT. This finding highlights that appropriate EIs are key for individuals to exercise their rights and enjoy their freedoms. Programs and institutional policies for people with disabilities should aim for such achievement of rights. Individuals with IDD flourish in inclusive programs.

The customization and sustainability of AT were valued by the staff. This finding may be a result of experiences of the staff with current AT or previous design experience with other student design groups. When AT is generic and does not fit well with the *Resources*, *Capabilities* and intended *Functioning* of the individual, their institution or other use settings, it could be discarded. Individualized design and flexible learning with a variety of interactive program elements played a significant role in building the custom AT that may otherwise not be available for the study participants. On the other hand, staff did request additional time over an 8-week training period for further development of AT. The adjustment in program time is justified in the wake of few ATs produced during the program not meeting individual *Capabilities*. For instance, individuals adopted the cup holder and leisure devices. Still, complex AT such as the can holder and joystick modification would require a lengthier or relatively comprehensive design intervention with additional stakeholders such as a wheelchair service provider. Makerspace programming should evaluate the feasibility of the design projects before pursuing them but not limit the inquiry to discovering the wants and needs of people with IDD. The authors ensured that environmental and structural factors, including institutional policy and practice, did not affect the inquiry on understanding the individual's internal *Resources*.

Broadly, the makerspace training program intervention paired existing *Resources* and *Capabilities* with a new makerspace *Resource* and delivered outputs of custom AT. This resulted in improved *Capabilities* for individuals with IDD and CLASS. The study findings should be valuable to institutions such as CLASS that host people with IDD for *Capability*-building. Federal and state agencies that sponsor such institutions and funding programs that fund capacity-building projects should support makerspaces and training services. The authors anticipate that CLASS can add a new AT design course to their suite of *Capabilities*-building courses with trained staff as instructors. Academic programs with AT product design and development could consider conducting classes in AT use settings or institutions where individuals frequent daily. Participants shall be engaged in an ownership role rather than as a consultant. These recommendations at the policy and institutional levels align with the concept of distributive justice as per the capability approach. The study emphasizes looking beyond the medical model and economic factors. It encourages equity for people with IDD who should enjoy equal rights and freedoms in society.

The theme of makerspace challenges highlights the limitations of the study and training program. The limited program time of 8-weeks, based on funding for the program, needs to be adjusted to the expected improvement in *Capabilities* and *Functionings* and type of AT to be developed. Technical jargon was reported by staff; it should be prevented through program evaluation before deployment. One of the study limitations was the lack of measurement of change in *Functionings*. This prevented an understanding of the effect of AT *Choices* on *Functionings*. Although the sustainability of the custom AT was praised, training programs should follow up on the usability and reliability of the AT devices. The authors recommend conducting makerspace training programs periodically to ensure that program outputs remain effective and valuable in the community and that people with IDD continue enjoying freedom.

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Appendix A. Knowledge Test

Staff#: ______

Directions: Read the following questions and to the best of your ability choose the correct answer by circling either a,b,c, or d. If you need clarification or help with a question, ask Alyssa for assistance. Good luck!

1. What type of filament is used with the Makerbot Sketch Desktop 3D printers?
    a. Polylactic acid (PLA) filament
    b. Acrylonitrile Butadiene Styrene (ABS) filament
    c. Nylon filament
    d. Polyethylene coTrimethylene Terephthalate (PETT) filament
2. Which of the following is NOT required to 3D printing an item?
    a. CAD Software
    b. Build Plate
    c. Extruder
    d. Phenolic Resin Cartridge
3. Which file format is used to 3D print an object?
    a. SLS
    b. STL
    c. SLT
    d. TCW
4. Which of the following fields or industries have used 3D printing?
    a. Art

   b. Medical & Dental
   c. Commercial
   d. All of the above

5. Choose the BEST definition of a makerspace.
   a. A public space where people from the community can come to build different technology objects.
   b. An area that elicits opportunities for the creation of an object utilizing the physical resources provided in the space.
   c. A place where people can gather to work on different projects while collaborating, sharing ideas, and using the equipment provided.
   d. An area designed to allow for the creation of a physical object though hands-on activities, such as wood working.

Thank you for completing this knowledge test!

Appendix B. Knowledge Survey

Staff#:______

Please place a checkmark in the box that best represents your current knowledge in the following areas:

Table A1. Knowledge survey.

	Very Familiar	**Somewhat Familiar**	**Not too Familiar**	**Not at All Familiar**
Makerspaces				
3D printing				
Computer aided design				
Addressing a client need through the creation of a 3D printed object				
The design process				
Creating AT devices using everyday materials				
General technology (phones, computer, etc.)				
Assistive technology devices				

Thank you for completing this knowledge survey!

Appendix C

Thank you for attending the CLASS Makerspace Training Program! The purpose of this survey is to understand your satisfaction with this training program to help improve the program in the future. Your participation is anonymous and confidential.

Directions: Please rate your level of agreement with the following statements by placing a check mark next to one of the four choices: strongly agree, agree, disagree, or strongly disagree.

Table A2. Satisfaction survey.

Satisfaction Questions	Strongly Agree	Agree	Disagree	Strongly Disagree
Objectives and Overall Content				
The planned objectives for the training program were met. Objective 1: Learn how to identify a client need. Objective 2: Learn computer aided design (Tinkercad) Objective 3: Learn how to/about 3D printing. Objective 4: Learn how to/about creating assistive technology devices using everyday materials				
The content was covered in depth.				
The length of the course (8 weeks) was enough time to learn the material.				
Method and Training Content				
The facilitators were well prepared.				
The content was easy to understand.				
The program had enough time for each topic.				
There was high degree of participation/involvement during the program.				
The training was realistic.				
The bi-weekly meetings with Alyssa were beneficial.				
The worksheets/surveys/assignments were helpful.				
I left the training with a better understanding of 3D printing.				
I am more confident in my skills related to 3D printing.				
I am more confident in my skills related to the design process.				
I am more confident in my skills related to computer aided design (Tinkercad).				
I have a better understanding of the makerspace.				
Collaborating with day program participants was beneficial.				
Usefulness and Overall Rating				
I am satisfied with the overall training program.				
I would attend a similar technology training program if offered in the future.				
The training was useful for my job.				
The training was useful for my personal development.				
Do you have any other comments to share about the training program?				

Thank you for completing this satisfaction survey!

Appendix D. Semi-Structured Interview Guide–Participant with IDD

Appendix D.1. Prior Experience

(1) What type of technology do you use in your daily life?
   a. Do you use any AT in your daily life? (shower seat, walker, cane, wheelchair, eating aid, reacher, etc.)
   b. Did you know about 3D printing before you started working with me? If so, where did you hear about it?
      i. TV, readings, lectures

   * Reminder: Training program consists of workshops on Thursday and classes on Friday with me. *

Appendix D.2. Training Program–Workshop

(2) In your opinion what was the best part of the training program? (workshops, classes)
   a. What workshop was the best and why? (needs assessment, Tinkercad, 3D printing, materials)
   b. Were there any workshops you did not like? Why?
(3) What is something you would change or add to the workshops to make it better?
(4) How did you feel about working with a staff member during the workshops?
   a. Was working with them helpful?
   b. Was working with them hard?

Appendix D.3. Training Program–Classes

(5) Were the makerspace classes on Friday helpful?
   a. What did you like about this class?
   b. What did you dislike about this class?
   c. What would you add to this class to make it better?
   d. Would you want to be involved in the classes and workshops if offered in the future?

Appendix D.4. Confidence/Skills Learned

(6) Do you like using Tinkercad/is it hard or easy for you? Why?
(7) Do you like or dislike 3D printing? Is it hard or easy? Why?
   a. Device, key chain
   b. Will you use 3D printing in the future?
(8) How did you like or dislike using mold/clay, twisty ties, and Velcro to making devices?

Appendix D.5. Makerspace

(9) What would you use the makerspace room for (room 118)? It would have a 3D printer and other materials.
   a. Positive/negatives?
(10) Is there anything else you would like to add that you did not get to say? Thank you!

Appendix E. Semi-Structured Interview Guide–Staff

Appendix E.1. Prior Experience

(1) What was your experience in relation to 3D printing before attending the training program?
   a. Design process, computer aided design, or creating AT out of everyday materials
(2) What exposure did you have in relation to the training program topics prior to the program?
   a. Prior knowledge

b. Readings, lectures, news

Appendix E.2. Training Program

(3) In your opinion describe/explain the most beneficial part of the training program.
   a. What resources/activities were the most helpful?
      i. Worksheets? Online surveys (multiple choice questions and fill in the blank) Bi-weekly meetings?
   b. What workshop was the most beneficial and why?
      i. What workshop did you enjoy the most?
(4) In your opinion describe/explain the least beneficial part of the training program.
(5) What is something you would change or add to the program to make it better?
(6) Describe your experience with collaborating with a day program participant during the program?
   a. How did you feel about this collaboration?
   b. Positive/negative aspects

Appendix E.3. Confidence/Skills Learned

(7) Tell me how confident you feel regarding topics learned in workshop?
   a. design process
   b. Tinkercad
   c. 3D printing
   d. creating AT out of everyday materials
      i. How knowledgeable do you feel regarding training program topics?
(8) How would you apply what you learned during the training program to a real-life scenario?

Appendix E.4. Makerspace

(9) What do you see for the future of the makerspace? This space would contain the 3D printer and other household materials.
   a. Facilitators? Benefits?
   b. Barriers?
   c. Training occurring in this space.
(10) Is there anything else you would like to add that you did not get to say?

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