Promoting Computational Thinking Skills for Blind and Visually Impaired Teens
Through Accessible Library Makerspaces

PROJECT JUSTIFICATION

The School of Information Sciences at the University of Illinois at Urbana-Champaign (UIUC) and the Champaign-Urbana (C-U) Community Fab Lab, in partnership with American Printing House for the Blind (APH), Young Adult Library Services Association (YALSA), and Reaching Across Illinois Library System Makerspace Networking Group (RAILS MNG), are requesting $498,638 for a National Leadership Applied Research grant project that will be conducted from August 2022 to May 2025. The project is also supported by the National Federation of the Blind (NFB) and UIUC's Disability Resources & Educational Services (DRES) and the Information Accessibility Design & Policy Program (IADP).

This project addresses the largely under-met need of young blind and visually impaired (BVI) learners in computational thinking and maker learning in libraries, with an aim to create more inclusive and accessible library makerspaces for BVI learners. This is one of the very few research projects conducted by, with, and for BVI learners, where our nonvisual approaches and sensory abilities, such as touching, hearing, smelling, and some remaining low vision, are utilized as a central asset. Instead of taking a retrofitted approach to fixing sighted and able-bodied design for disabilities, we flip the model in a way that our blind researcher and participants and their unique expertise take a pivotal role in realizing the full potential of multi-modal maker learning, beyond the current vision-dominant maker tools and approaches, and fostering a more accessible makerspace design for people of all abilities.

Program goals and associated objectives

The project aims to generate new research findings; services, programs, and practices; and alliances that can be widely used, adapted, scaled, or replicated in libraries and other informal learning settings. We address the IMLS National Leadership Grants for Libraries grant program *Goal 1: Build the workforce and institutional capacity for managing the national information infrastructure and serving the information and education needs of the public* and all three of its Objectives, including developing replicable library programs, models, and tools to support learning—in particular, informal maker learning to promote computational thinking skills (Objective 1.1), collaborating with learning organizations, such as libraries, national professional organizations, and universities (Objective 1.2), and creating and facilitating opportunities for continuous learning for individuals with disabilities (Objective 1.3).

The current challenge

Like their sighted counterparts, blind and visually impaired (BVI) teens have a holistic developmental need that can be met through different physical, cognitive, and emotional engagements in a socially supported setting. Just like other teens, BVI teens have a natural desire for social opportunities and are interested in playful hands-on activities. According to the Connected Learning theory, "learning is irresistible and life-changing when it connects personal interests to meaningful relationships and real-world opportunities." (Connected Learning Alliance, n.d.). Where do BVI teens experience such powerful social learning and create connections to real-world career and civic opportunities? The statistics about the employment rate for the blinds or visually impaired are devastating. Only 44 percent of people who are blind or visually impaired are employed, compared with 79 percent of those without disabilities (McDonnall & Sui, 2019). According to *A Guide for College Students With Visual Impairments* (2020), in 2015 less than 15% of BVI individuals had earned a bachelor's degree at an accredited higher learning institution, and more than a quarter do not finish high school. As many as 29% of people who are blind or visually impaired currently live below the poverty line. BVI individuals' participation in STEM (Science, Technology, Engineering, and Math) area is even scarce. As Beck-Winchatz and Riccobono (2008) accurately describe, "these students are often at a disadvantage in science because of the ubiquity of important graphical information that is generally not available in accessible formats, the unfamiliarity of teachers with non-visual teaching methods, lack of access to blind role models, and the low expectations of their teachers and parents" (p. 1855).

Accessible making for all in library makerspaces

Maker education, a hand-on learning approach where learners create meaning and solve problems as they interact with tangible objects and technologies (Dougherty, 2012; Halverson & Peppler, 2018; Halverson & Sheridan, 2014; Koh et al., 2019), seems promising for engaging BVI learners, owing to its physical, tactile, and multimodal nature. For example, a National Science Foundation (NSF)-funded project, *Build a Better Book*, engages youth in the design and fabrication of inclusive media that incorporate tactile and audio features in school and library makerspace. Throughout the project, participating teens develop technology skills and learn about STEM careers (Forsyth et al., 2020). The Andrew Heiskell Braille and Talking Book Library of the New York Public Library (NYPL), one of the America's oldest public libraries serving BVI patrons and people with print disabilities, offers various maker workshops for BVI learners as part of their assistive technology and technology coaching services. The services include not only basic computer skills, but also advanced computing topics, such as non-visual coding and robotics, GarageBand, and photography and videography that can promote BVI learners' interests in STEM subjects. Besides these handful of pioneering cases, however, the full potential of maker learning for BVI learners is under-explored and not widely practiced. Currently, major tools and approaches adopted in makerspaces, such as 3D design, modeling, and prototyping, and associated maker activities are highly vision dependent and largely unusable by BVI makers (Bennett et al., 2019; Miele, 2017; Seo, 2019).

Nowadays a number of libraries offer a makerspace and/or opportunities for maker learning. While the initial maker movement in the U.S. has been criticized because of its inequitable participation, such as gender inequities (Brahms & Crowley, 2016; Buchholz et al., 2014; Buechley et al., 2008; Melo & Nichols, 2020) and cultural/racial inclusivity issues (Britton, 2012; Calabrese Barton & Tan, 2018; Kafai et al., 2014), scholars in the maker movement suggest makerspaces housed in libraries—a free space open to the general public with a mission of supporting lifelong learning and democratization of access to information—hold its promise to equity in makerspaces (Halverson & Peppler, 2018; Koh et al., 2018; Martin, 2015). In contrast to the growing body of literature on equitable and inclusive making, only a small number of literature exist regarding the accessibility of makerspaces (Alper, 2013; Brady et al., 2014; Hurst & Kane, 2013; Seo & Richard, 2021). In an exploratory study conducted in the District of Columbia Public Library (DCPL), Brady et al. (2014) suggest that an accessible library makerspace for patrons with cognitive and visual impairments is beneficial in promoting their STEM interests and various learning and social skills through collaborative activities. Research suggests the Do-It-Yourself (DIY) approach to designing assistive technologies, such as 3D printing grips, for people with disabilities can be an empowering experience (Buehler et al., 2014; Hurst & Tobias, 2011; Meissner et al., 2017). Some studies underscore the positive impact of mixed-ability maker culture, "a collaborative culture within which people with and without disabilities can co-exist and co-create as they work to maximize and develop their own skills" (Alper, 2013). Benton and colleagues (2012), for example, demonstrated a successful mixed-ability participatory design team within which children with and without Autism Spectrum Disorders (ASD) positively collaborated with one another in the technology design process of a math game. Similarly, Buehler et al. (2015) reported their positive experience on teaching 3D printing to young adults with intellectual disabilities in an integrated post-secondary course. A review of literature reveals that, besides the small number of literature that focuses on learning disabilities (Anthony et al, 2012), accessible making across various dis/abilities, especially blindness and visual impairments, has received little attention and remains under-practiced (Alper, 2013; Brady et al., 2014; Hurst & Kane, 2013; Seo & Richard, 2021).

Promoting computational thinking skills for BVI teens through maker learning

The focus of our project, in particular, is on *fostering computational thinking skills for BVI teens, as a way of supporting their agency, introducing STEM mindsets, and increasing career opportunities, through making.* Wing (2006) defines computational thinking (CT) as a universally applicable attitude and skill set for everyone, not just computer scientists, which "involves solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science" (p. 33). There are varying, and often critical opinions on the benefits of computational thinking for all, such as computer programming for developing logical thinking, persistence, science and math skills, emotional value, agency, motivation, understanding on the world around them, career opportunities, diversity in the tech industry, and college computer science major preparedness

(Lewis, 2017). While we acknowledge "teaching computer science is not a silver bullet or panacea," (Lewis, 2017, p. 15), in this project we argue computational thinking skills have a potential to increase BVI teens' (a) ability to connect and participate in the world, (b) interests in STEM, and (c) career opportunities. Computational thinking skills is a powerful tool for creation, self-expression, sharing, and participation in the world for BVI teens, who often experience participation barriers in their social and civic communities. Kafai and Burke (2014) suggest "programming is not just a cognitive skill that is used to design code. It also is a social and cultural skill that is used to participate in groups" (p. 28). Computational thinking activities, such as coding and making, can allow students to create, share, remix, and discuss their making artifacts as "a communal practice that reflects how students today can participate in their communities" (Kafai & Burke, 2014, p. 128). Also, while the early notion of computing in the K-12 context focused heavily on procedural thinking and programming, a fresh 21st century perspective to computing is being viewed as at the core of all STEM disciplines (Grover & Pea, 2013; Henderson et al., 2007). Studies suggest, if designed intentionally, computational thinking skills can be aligned to reinforce or introduce other STEM domain knowledge and skills. Finally, although the purpose of computational thinking skills and maker learning in general is far beyond workforce development, considering the unique challenge that the BVI population is currently facing (i.e., significantly low employment rates), we argue there is an urgent need to teach BVI teens computational thinking skills in order to open up more future possibilities and relevant career preparation across a variety of domains.

Unfortunately, the current computational thinking education, such as coding, robotics, and making, further marginalizes BVI teens' participation, due to inaccessible learning materials and a lack of non-visual teaching strategies (Beck-Winchatz & Riccobono, 2008). For example, Ludi and Spencer (2017) highlight that block-based programming languages and tools, such as Scratch (Resnick et al., 2009) and Blockly (Fraser, 2015)—two of the most widely used tools to introduce youth to computational thinking concepts, pose an obstacle in broadening participation for many BVI learners. Because such block-based tools and environments require visual interactions and drag-and-drop features, BVI teens are unintentionally excluded from the opportunities to learn and participate in computing activities (Ludi & Spencer, 2017). Multi-modal tangible making, such as physical coding with robotics and snap-together electronics, offer a great potential to fill this gap. In his previous maker workshops, the PI successfully utilized Kibo—a wooden brick physical robotics kit—to teach basic computer programming concepts to BVI young adults (Seo & Richard, 2018, 2020). Similarly, other exploratory projects have shown the benefits of using tangible maker kits (e.g., LEGO Mindstorm RCX Robotic Platforms) as a way of introducing computing concepts to BVI youth (Dorsey et al., 2014).

The proposed research

This applied research aims to advance both theoretical and practical knowledge on accessible maker approaches to promoting computational thinking skills for BVI learners. As one of the very few projects led by, and conducted with, and for the BVI populations, the project is motivated by the PI's lived experiences and expertise as a BVI teen in the past and now as a blind STEM researcher and educator. The project takes an asset-based approach to developing, implementing, and disseminating accessible maker programs in informal learning environments, in particular, library makerspaces. Our national and state partnerships, advisory board members, and supporters intersect multiple sectors, including the national organization for BVI people (APH; NFB), national library services for teens (ALA YALSA), regional library makerspace communities (RAILS MLG), librarians and accessibility educators, and university researchers in Library and Information Science, Computer Science, and Science Education.

Target group and beneficiaries

The target group of our project (i.e., those who will be most immediately and positively affected by our project) include maker professionals, librarians, and BVI teens who participate in the project. We estimate *a total of approximately 120 teens and adults* will directly be engaged (including ~50 BVI teens and 10 librarians and 10 Fab Lab professionals who will directly work with the BVI learners and/or receive training on makerspace accessibility, and ~10 iSchool students, ~40 librarians who will attend our hands-on training workshops in the YALSA' Young Adults Services symposium and Illinois Library Association Annual Conference). In addition,

there are potentially hundreds of librarians and maker professionals who may attend our webinars and other conference sessions.

Phase	Locations	Approximate number of the target groups/participants
1	The C-U Community Fab Lab	• 10 Fab Lab maker professionals (accessibility training) • 5 iSchool Independent Study students (FA22)
2	The C-U Community Fab Lab summer camp	• 10 BVI teens • 5 iSchool Independent Study students (SP23)
3	4 different partner library makerspaces in IL	• 2-3 librarians from each site • 10 BVI teens from each site • 20 Illinois Library Association workshop participants
4	20 YALSA's symposium participants	
TOTAL	~ 120 directly engaged teens and adults	

[Table 1. Target group and beneficiaries]

The ultimate beneficiaries for the project (i.e., those who are likely to be aided in the long-term) includes not only BVI teens and librarians with enhanced competencies for serving diverse youth, but also all makers and library users in a more inclusive and accessible library makerspace.

PROJECT WORK PLAN

Participatory design research

The project will conduct *participatory design research* over 34 months with university researchers, BVI teens, librarians, and maker professionals. Grounded in both theories and practices, design research seek to solve a real-world problem by designing and enacting interventions through iterative refinements (Brown, 1992; Collins, 1992; Hoadley, 2004; Land & Zimmerman, 2015; Rawson & Hughes-Hassell, 2015; Reisman, 2008). Unlike experimental studies where participants are seen as target subjects in a controlled lab setting, design research considers study participants as design partners who can provide essential ideas to make a better solution (Brown, 1992; Hoadley, 2004). Our project invites BVI teens, librarians, and maker professionals as our co-designers and partners to foster more inclusive and accessible library makerspaces.

Theoretical perspectives: constructionism, ability-based design, and collaborative interdependence

Building on sociocultural constructivism (Vygotsky & Cole, 1978), which explains learning is a cultural process in which people learn through social interactions with others, Papert's constructionism (1991; 1993) focuses on "learning-by-making." According to Papert (1993), playful physical artifacts can effectively mediate and develop children and youth learners' logical thinking, including mathematical and computational concepts. By engaging in interactive maker activities with "objects-to-think-with", learners construct meaning and reflect on their knowledge building processes (Papert, 1993).

Ability-based design suggests design principles that shift the focus of accessible design from disability to ability in order to create systems that leverage the full range of human potential (Wobbrock et al, 2011). Ability-based design consist of seven principles (Ability; Accountability; Adaptation; Transparency; Performance; Context; and Commodity), these are then divided into three categories and recommendation levels: (a) stance (principles 1-2; required), (b) interface (principles 3-6; recommended), and (c) system (principle 7; encouraged). The required stance of the first two principles strongly influences our work:

1. Ability: Designers will focus on ability not dis-ability, striving to leverage all that users can do;
2. Accountability: Designers will respond to poor performance by changing systems, not users, leaving users as they are (Wobbrock et al., 2011, p. 11).

Instead of viewing BVI teens' visual impairments as medical disabilities or deficiencies, our project, focuses on our participants' "abilities" (Oliver, 2013; Wobbrock et al., 2011) by adventuring into a variety of non-visual and tangible "objects-to-think-with" (Papert, 1993) approaches.

In addition to the existing participatory design frameworks (McDowell, 2015; Yip & Lee, 2018) that offer insights into how to co-design with different stakeholders, we draw on a concept of *collaborative interdependence* (Bennett et al., 2018) for co-designing with BVI and librarians across dis/abilities. According to Bennett and colleagues (2018), the interdependence framework contrast with the traditional perspective of independence of the people with disabilities, which "ignores the fundamental interdependence of all bodies for sustenance, community, and care" (Hamraie, 2013), and therefore perpetuates the systemic isolation of people with disabilities. Rather than designing for people with disabilities from a distance, interdependence highlights the vital contributions of people with and without disabilities, because access is indeed relational, mutual, and simultaneous between people with and without disabilities.

Design and Research questions

An emerging body of literature suggests an overlap between design process and social science research methods (Nakano et al., 2018). In this design research project, we propose both design questions and research questions. Our design questions are framed as *How Might We* questions (IDEO, 2015), where *How* is solution-oriented, *Might* encourages optimism, and *We* is collaborative. The research questions are to be answered through in-depth qualitative inquiry and multiple case study approaches.

Our overarching design question [DQ] is: *how might we create library makerspaces that are more welcoming, inclusive, and accessible for our blind and/or visually impaired teens?* Specifically, we ask:

- DQ1. How might we increase librarians and maker professionals' competencies to work with BVI populations?
- DQ2. How might we create more accessible maker tools and activities that foster computational thinking skills for BVI teens in libraries?
- DQ3. How might we create maker learning approaches and curriculum that realize its full potential of physicality, tactility, and multimodality, beyond the current vision-dominant approach?

In this research, we seek to investigate the experiences and perceptions of two target populations: (1) BVI learners and (2) librarians and maker professionals who design and facilitate accessible maker learning with BVI learners. The proposed research questions are:

- RQ1. How does the tangible and accessible maker curriculum developed in this project affect BVI teens' perceptions of libraries, sense of agency, STEM interests, and career opportunities?
- RQ2. What changes does the tangible and accessible maker curriculum make, if any, on BVI teens' computational thinking skills?
- RQ3. What are the perceptions and experiences of librarians and maker professionals who design and facilitate accessible maker learning with BVI learners?

Due to the exploratory nature of the project, research questions at this point are intentionally broad. As we go through the iterative phases and conduct the program in different settings, we anticipate more specific questions may arise.

Research Design

The project consists of four phases: Phase 1 (6 months): study setting assessment, preparations, and staff training in the C-U Community Fab Lab; Phase 2 (6 months): prototype design and testing in the C-U Community Fab Lab; Phase 3 (12 months): implementation in 4 different library makerspaces (Illinois); Phase 4 (10 months): debrief, synthesis, and dissemination.

The Champaign-Urbana [C-U] Community Fab Lab—the study setting for prototype development, testing, and summer camp, in the first two phases—is a makerspace located on the UIUC campus in Urbana, Illinois. The fab lab supports both on- and off-campus community members through university courses, research, on-and off-campus outreach, community programming, K-12 summer camps, and open access design and fabrication support

for all students, staff, faculty, and the community. The lab has offered more than 40 summer youth week-long half-day camps, 25 of which were unique camp curricula each year, with several new camps each year, and welcome over 300 youth, ages 5-18, participants each summer. The lab has developed long-term partnerships with local libraries and afterschool programs, regularly facilitating teen open lab and STEM/maker activates in the community partner sites (See more information at http://cucfablab.org/programs-and-services/).

The C-U Community Fab Lab will provide a space to design and test a prototype model for accessible makerspaces, to be disseminated and adapted in other library makerspaces in later phases, because experimenting with exploratory services and tools can be a daunting task for librarians who deal with day-to-day operations and accountability, which is often a barrier to offering innovative services for marginalized groups. We also recognize challenges of collecting research data from users (e.g., in-depth interviews or multiple surveys) in public or school libraries and makerspaces without interfering with their normal daily operations. While many librarians are willing to participate in interviews and other forms of feedback sharing with the researchers, some libraries' policies may not allow, understandably, intensive research activities for their patrons. Therefore, more rigorous data collection methods from BVI participants will be applied in Phase 2 in the C-U Community Fab Lab. In Phase 3, which are conducted in various library makerspaces in its locations, sizes, and capacities, we will test the transferability and flexibility of our newly designed accessible maker programs. Phase 4 is devoted to conducting a debrief with all partners and advisors, data analysis, and making wide and effective disseminations. See Schedule of Completion for a detailed timeline.

Phase 1 (Aug 2022 – Jan 2023). Study setting assessment and staff training
Focusing on our first design question: *how might we increase librarians and maker professionals' competencies to work with BVI populations?,* Phase 1 includes (1) staff training on accessible makerspaces and (2) assessing the current accessibility status of the C- U Community Fab Lab. Working with the Disability Resources & Educational Services (DRES) and the Information Accessibility Design & Policy Program (IADP) in the university, the research team will develop and deliver a series of workshop trainings for librarians and maker professionals to address empathy building, core accessibility concepts (e.g., medical vs. social models of disabilities and Web Content Accessibility Guidelines), the principles of universal design and ability-based design, safety and liability issues, and more. Accessibility experts from other libraries and agencies will also be invited. After each workshop, an evaluation form will be collected to receive feedback from the staff members. In addition, the PI and co-PI will offer an independent study course on accessible library makerspaces at the UIUC iSchool, in which undergraduate and graduate students can deepen their understanding of accessibility issues in library makerspaces by getting directly involved in the project activities, such as workshops and accessibility evaluation.

At the same time, the team will systematically evaluate and document the current accessibility status of the C-U Community Fab Lab to address potential barriers against BVI populations. According to the seven principles of universal design (UD) (Center for Applied Special Technology, 2011), the evaluation process will include assessments on building access, facility arrangement, assistive technology availability, and more. The evaluation results will be compiled as a report or a guide to designing accessible library makerspaces. All the learning resources, workshops, and space/facility/assistive technology guidelines developed in Phase 1 will be documented, recorded, and shared through the C-U Community Fab Lab website and other partners' channels. *IRB* for the entire project will be obtained during Phase 1.

Phase 2 (Feb – July 2023): Prototype design and implementation
Phase 2 focuses on DQ2: *how might we create more accessible maker tools and activities that foster computational thinking skills for BVI teens in libraries?* and DQ3: *how might we create maker learning approaches and curriculum that realize its full potential of physicality, tactility, and multimodality, beyond the current vision-dominant approach?* We will investigate all three research questions, except the teens' perceptions on libraries and librarians' perceptions and experiences, which will be further pursued in Phase 3.

Prototype development; recruitment and research instrument development (Feb – May 2023). We will spend the first 4 months of the Phase 2 to get prepared to implement a three-day summer camp for BVI teens. We partner with the American Printing House for the Blind (APH), the world's largest nonprofit R&D organization for the blind who has developed accessible maker toolkits and instructional materials for blind young learners, such as Code Jumper, Snap Circuits/Bric Access Kit, and Snapino access kit. These tools and materials, however, have not widely been used in museum and library makerspaces, and the APH has not yet developed integrated learning curricula and maker activities that encompass both coding and electronics skills using these tools. Therefore, this phase aims to develop accessible and integrated learning-by-making activities and curriculum for BVI leaners, which will be implemented and tested in the summer camp. The prototype development will be led by the PI and RA, then they will train the fab lab staff members who will facilitate the summer camps for BVI teens.

Data collection instruments, such as interview questions, surveys, and think-aloud protocols, will be developed considering the need and characteristics of our BVI participants. While we may avoid a heavily vision-dependent method, such as video analysis, and rather design creative approaches to collecting other sensory data, the sighted collaborators in this project will contribute to capturing some visual data to supplement through observations and recordings as well. Participant recruitment will be undertaken during this time. Approximately 10 BVI learners between 7th and 12th grades will be recruited around Champaign and Springfield Illinois, with the aid of the National Federation of the Blind (NFB), which is the oldest and largest nationwide organization led by blind people in the United States.

The C-U Community Fab Lab summer camp; data collection & analysis (June-July 2023). A three-day summer camp will be hosted in the C-U Community Fab Lab in early June 2023 tailored for BVI teens to promote their computational thinking skills. The participants will receive a free registration, 2-night hotel stay (if needed), working lunch, and accessible maker kits they can take home after the camp. They will be asked to participate in research activities (e.g., interviews, surveys, and think-aloud) and for permission to take and use the photos/videos for the research and dissemination purposes, by agreeing on the minor assent and parent consent forms and protocols. Due to the uncertainty around the COVID-19, the workshops may be conducted in other places or virtually. The Fab Lab staff members, who are experienced maker professionals and accessibility-trained during the earlier phase, will walk our BVI participants through three core activities in each session (i.e., coding; electronics; and integrated prototyping). Each session will last for three hours.

The first session focuses on coding (software engineering) education with Code Jumper. Code Jumper is a physical coding platform designed and developed by Microsoft and APH for blind young learners. Through tangible making activities, our participants will learn core computer programming concepts, such as variables, input, output, conditions, and loops. In the second session, participants will be introduced to electronics (hardware/electrical engineering) education using Snap circuits and BRIC. Snap Circuits Access Kits are accessible snap-together maker tools redesigned by APH for blind kids. Through series of making projects, participants will engage with basic electronics concepts, including circuits, current, resistance, switches, and motors. In the last session, participants will have more advanced experience with software-hardware (computer engineering) education using Snapino. Snapino is an easy-to-use Snap Circuits version of Arduino that integrates coding into electronics. BVI teenagers will have a chance to learn prototyping skills, building upon what they will have acquired in the previous days. This approach will allow learners to interweave software-hardware engineering knowledge and maximize their creativity and computational thinking skills.

PI, Co-PI, and RA will be present during the entire camps to collect data. Qualitative data collection methods will be used before, during, and after the summer camps, to answer research question 1 and 2 (except for the participants' perception on libraries). Qualitative semi-structured interviews will be used before and after the summer camp to ask participants about their prior making/coding experience; how this camp affected their interests/self-efficacy in STEM+C subjects/careers); and design feedback on making tools and activities. Also, the think-aloud protocol (Van Someren et al., 1994) will be utilized and audio-recorded during each of the three

sessions to learn how the participants vocalize their learning-by-making processes. After the summer camp, a focus group interview will be conducted with the fab lab staff members who facilitated the camp in order to answer research question 3 and obtain design feedback. Qualitative data analysis will be conducted by PI, Co-PI, and RA.

Phase 3 (Aug 2023 – Jul 2024): Implementation in library makerspaces.
Phase 3 addresses all design and research questions. The prototype tools and activities developed in Phase 2 will be disseminated and implemented in 3 or 4 different library makerspaces in Illinois, recruited through the RAILS Makerspaces Networking Groups (MNG)—a group of librarians working in library makerspaces in Illinois—and selected based on their need and capacity. A purposeful selection will be made to represent various library makerspaces and test the transferability and flexibility of the program. For example, some libraries may or may not have a dedicated space or maker professionals; rather, a youth services or technical librarian might run a maker program. A preliminary inquiry has been sent in early 2022 to the RAILS MNG, and initial responses from several Illinois libraries with differing sizes, capacities, and degrees of familiarity with BVI population showed that there is an existing need and interest in this area. Up to 40 BVI learners (~10 participants per library) will be engaged. The research team and the C-U Community Fab Lab staff from the Phase 1 and 2 will provide training and assistance needed to implement the program. The accessible maker tool kits needed to implement the program will be distributed, which each library will keep after the project for their future use, in an effort to encourage sustainability of the program in each site. In addition, the research team, working with RAILS MNG, will deliver a hands-on workshop in the Illinois Library Association Annual Conference to train librarians and develop a network of librarians who serve BVI learners and people with disabilities.

Multiple case studies (Stake, 2013) will be conducted to qualitatively compare different experiences of librarians in hosting accessible maker programs for BVI patrons across different library settings. The PI and RA will travel to visit all 4 libraries and conduct individual or group interviews with librarians who facilitate the program. Contingent upon COVID-19, this might be replaced with a zoom interview. Building on the existing teen program evaluation tools that have been tested in several libraries (See the Capturing Connected Learning in Library project: https://connectedlearning.uci.edu/project/capturing-connected-learning-in-libraries/), the PI, Co-PI, and RA will work with librarians from each site to develop fun, less-obtrusive, and on-the-fly program evaluation methods for BVI patrons. Further specific data collection strategies from BVI teens will be determined according to each library's policy and procedures.

Phase 4 (Aug 2024 – May 2025). Disseminations and debrief.
In Phase 4, we will reach out to as many librarians and maker professionals as possible through different venues. Key milestones in this phase include a hands-on workshop in the YALSA's Young Adult Services Symposium in November 2024, as well as a YALSA webinar, which has a potential to reach out hundreds of librarians across the country. After participation, the workshop and webinar attendees will increase their knowledge on accessible library makerspaces, accessible maker programs for BVI learners that participants can implement in their own library. We will also disseminate the training materials and a guide to an accessible makerspace developed in earlier phases. Participants will be asked to fill out webinar/workshop evaluation forms.

Debrief sessions will be held with all partners to share their experiences in this project, discuss challenges and opportunities of the current maker tools and activities for BVI learners, and to identify future directions. The project results will be synthesized in a replicable framework and report and will be distributed through various channels, including but not limited to: conference presentations and workshops, journal papers, webinars, websites, and social media. The dissemination venues will target both scholarly and practitioner communities. Our national and regional partners and advisory board members will be instrumental for wide and effective disseminations of the project. For example, YALSA will actively disseminate our project through their various channels. We will closely work with the APH for a nationwide distribution of the accessible and integrated maker curricula, as APH has several online channels and archives of accessible learning materials for BVI learners, educators, and their families. It is important that we distribute our results in accessible platforms, and working

with various partners and collaborators, we hope to be able to address the current accessibility issues of their platforms and channels.

DIVERSITY PLAN

By engaging one of the most marginalized populations in the maker movement in libraries and in society, the project strongly upholds the IMLS' emphasis on diversity, equity, and inclusion. This applied research project will be a significant step toward creating a more inclusive library makerspace for all abilities.

Just as curb cuts help more than a person who uses a wheelchair, accessibility features added to maker tools and learning materials can make the system more usable by everyone. Ronald Mace (1998) suggest that universal design is designing all products and our environments "to be aesthetic and usable to the greatest extent possible by everyone, regardless of their age, ability, or status in life" (p. 23). Ultimately, our project aims to design accessible makerspace and maker learning for all, including but not limited to BVI teens. The tangible making activities and integrated curricula co-designed by and for blind participants will bring the current maker movement a new insight into how we can broaden the participation of maker and STEM learning for underserved populations of diverse abilities. The project outcomes will inform the design of multi-modal maker learning, beyond vision-dominant affordances, for learners of all abilities.

We realize that librarians and maker professionals' lack of experience of serving people with disabilities is one of the greatest challenges in creating a more accessible library makerspace (Brady et al., 2014). This is largely owing to the paucity of training and networked resources for librarians. While libraries seek to be "open to all, regardless of all abilities", many librarians rarely have an opportunity to engage in hands-on accessible design projects in either their pre-service or continuing education period. Our project will fill this significant gap by actively engaging pre-service librarians in the iSchool through Independent Study, increasing the competence and confidence of each librarian who participates in the project, and reaching out to many librarians through hands-on workshops, webinars, and other resources. Our project will offer accessibility training and networking opportunities for participating librarians to exchange their experiences and ideas around accessible maker programming for BVI teens. By hosting their own accessible maker sessions for blind teens in their libraries, librarians will gain practical knowledge about how to serve patrons with disabilities. The C-U Community Fab Lab, as a central hub for the project, will facilitate and support other libraries as they provide accessible maker programs in their local areas.

PROJECT RESULTS

The intended results of the project (i.e., concrete outputs) include: (1) training materials for librarians and maker professionals on accessible making, including a guide to develop an accessible library makerspace; (2) accessible maker programs tailored for BVI leaners to increase their computational thinking skills across coding and electronics; and (3) research findings on accessible making and computational thinking skills for BVI learners; competencies, perceptions, and experiences of librarians on serving people with disabilities through accessible making. All tutorials, curriculum, workshops, guides, and resources developed in this project will be freely available on the C-U Community Fab Lab website, which will be maintained even after the project ends, and promoted through the marketing and communication teams from the iSchool, the C-U Commuinty Fab Lab, and partners (YALSA, APH, and RAILS MNG). Our research findings will deepen an ecological understanding on how accessible library makerspaces can support BVI teens' interest development in STEM+C subjects and careers, and will be published and presented in scholarly and professional venues.

Potential outcomes (i.e., meaningful changes in people and society) include (1) participating BVI teens' enhanced computational thinking skills, STEM interests, sense of agency, and career opportunities; (2) participating librarians' and maker professionals' increased competencies and confidence working with BVI populations; and knowledge on accessibility in makerspaces; (3) increased awareness on accessible makerspaces through our nationwide dissemination and promotion; (4) networks and partnerships among reginal and national organizations

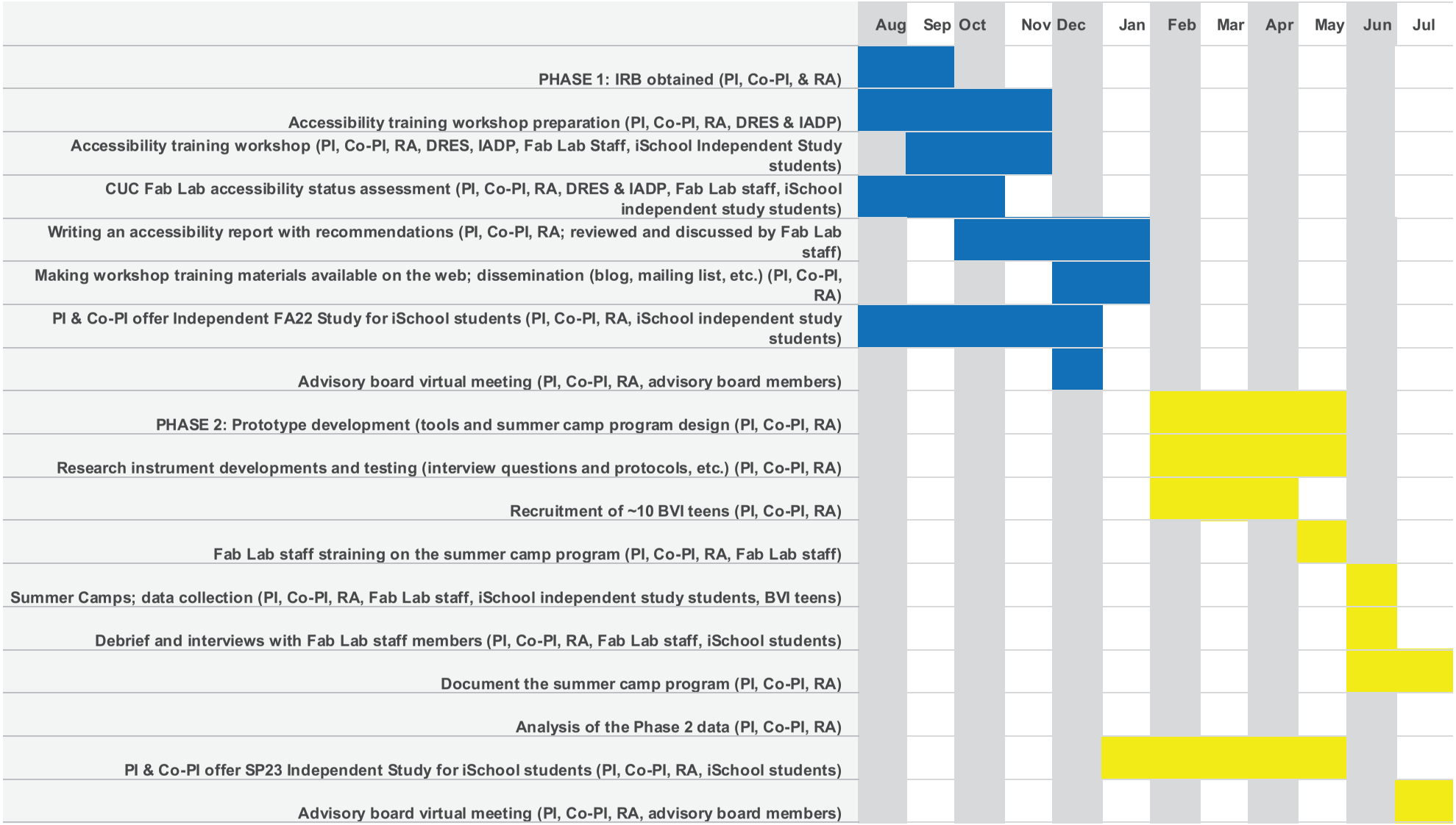
for librarians, maker professionals, and BVI people; and (5) advanced knowledge and theory in the area of accessible and inclusive making.

Phase	Milestones	Results	Outcomes	Measures
1	• 3 professional training sessions • Fab Lab accessibility assessment	• Training materials and a guide to designing an accessible library makerspace	• Maker professionals' increased knowledge on accessibility	• Feedback/evaluation on the training from participating maker professionals
2	• Summer camp	• Accessible maker programs tailored for BVI leaners • Research findings	• Maker professionals' increased competencies and confidence in serving BVI people • Participating BVI teens' enhanced computational thinking skills, STEM interests, sense of agency, and career opportunities	• Feedback from participating maker professionals (interviews) • Survey, interview, observation, think-aloud results from BVI teens
3	• Accessible maker programs in 4 different library makerspaces • Illinois Library Association workshop with RAILS MNG	• Tested and refined accessible maker programs for BVI teens • Research findings	• Librarians' increased competencies and confidence in serving BVI people • Participating BVI teens' enhanced computational thinking skills, STEM interests, sense of agency, and career opportunities	• Feedback from participating librarians (interviews) • Program evaluation from each site • Acceptance to present findings in conferences or journals
4	• YALSA's Young Adults Services symposium • YALSA webinar • Debrief meetings	• White paper • Delivered presentations and submitted/published papers • Future agenda	• Increased awareness on accessible makerspaces • Networks and partnerships • Advanced knowledge and theory in the area of accessible making.	• Partners and advisors' feedback through debriefs • Workshop and webinar evaluation • Acceptance to present findings in conferences or journals

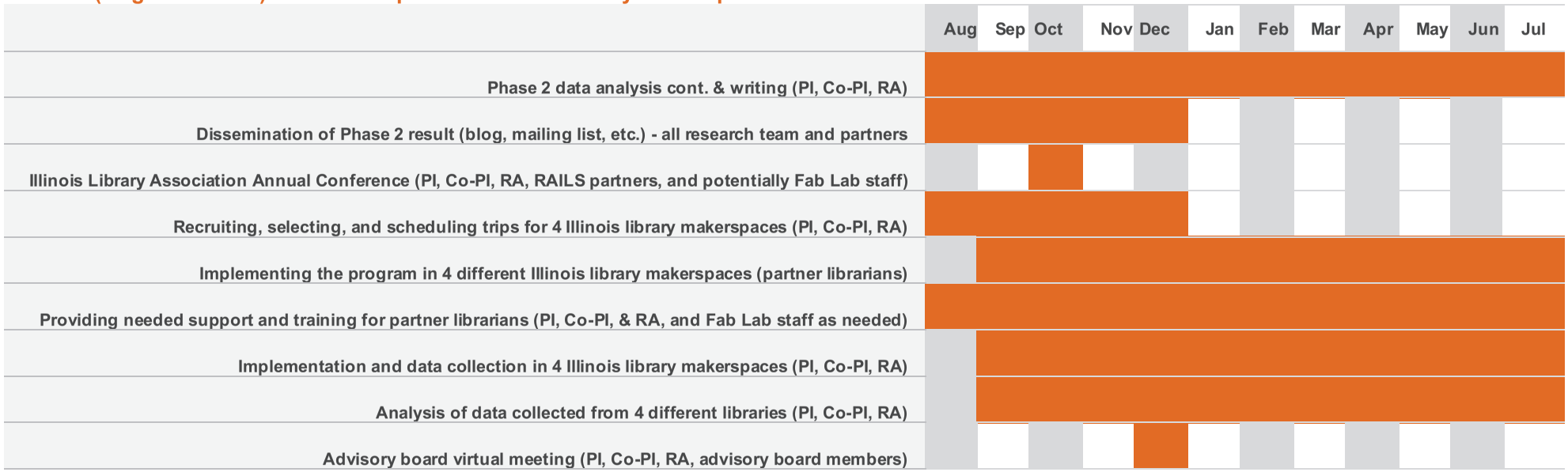
[Table 2. Project milestones – results- outcomes - measures]

By testing a prototype program rigorously developed in the C-U Community Fab Lab in different library makerspaces, we will ensure the flexibility and transferability of the accessible library programs and guidelines. The Co-PI, the director of the C-U Community Fab Lab, working with the university's DRES, IADP, and the PI, will ensure the lab continues innovating its accessible tools and programs and supporting other libraries to improve their accessibility. The core values of inclusivity and accessibility will be inscribed in the lab's strategic plan for 2022-2025. The PI and Co-PI will continue offering Independent Study, with an aim of eventually turning it into a regular course(s) for pre-service and current librarians to increase their competencies to serve people with disabilities. The Illinois libraries participated in this project will keep the accessible maker kit, in a way of encouraging the sustainability of the program. Toward the end of the project we will generate a clearly identified future agenda to advance the area of accessible making with solidified partnerships.

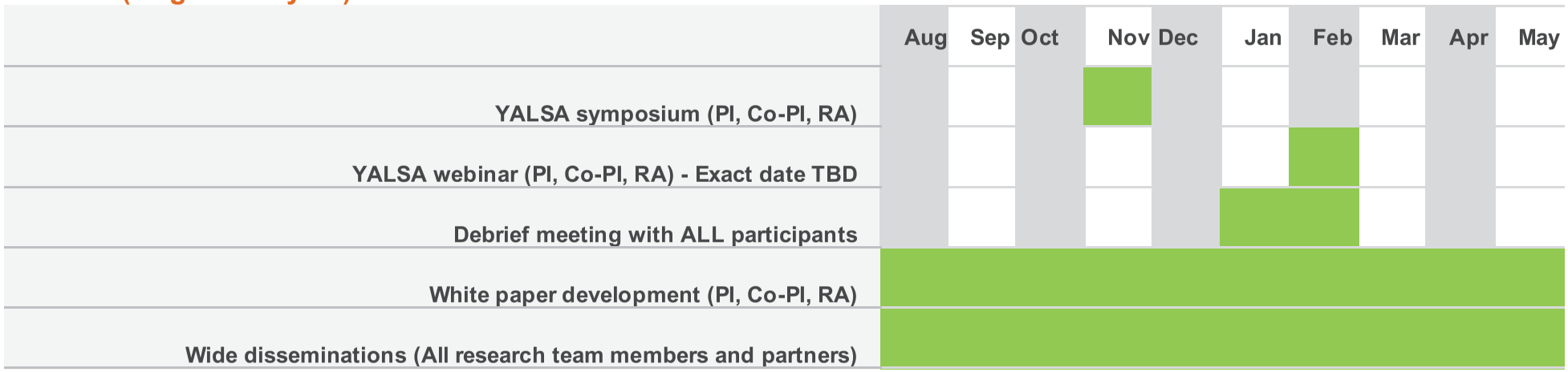
Year 1 (Aug 22 - Jul 23): Phase 1 & 2



Year 2 (Aug 23 - Jul 24): Phase 3 Implementation in library makerspaces



Year 3 (Aug 24- May 25): Phase 4 Dissemination and debrief



Digital Products Plan

Type

What digital products will you create? Most projects are likely to generate digital content, resources, or assets. They may be digitized or born-digital products created by individuals, project teams, or through community gatherings. Examples include, but are not limited to, still images, audio files, moving images, microfilm, object inventories, object catalogs, artworks, books, posters, curricula, field books, maps, notebooks, scientific labels, metadata schema, charts, tables, drawings, workflows, teacher resources, and software, including source code, algorithms, applications, and digital tools, plus accompanying documentation. In your Digital Products Plan, describe the digital content, resources, or assets you will create or collect, the quantities of each type, the digital file format(s), the accompanying metadata, and any relevant standards you will use. If you are developing software, you should also specify the programming languages, platforms, frameworks, software, or other applications you will use to create your software and explain why you chose them.

Accessible makerspace guidelines and accessible maker education curricula will be created in MS Word and be available in HTML in accordance with the Web Content Accessibility Guidelines (WCAG) version 2.1 AA compliance level. The digital output can be read using the freely available web browsers, such as Google Chrome, Mozilla Firefox, Microsoft Edge, Apple Safari, and other browsers supporting web standard, for people with and without dis/abilities.

Availability

How will you make your digital products openly available (as appropriate)? IMLS encourages grant recipients to make works produced with IMLS support widely available, and to share their work products (including publications, datasets, educational resources, software, and digital content) whenever possible through free and open-access journals and repositories. Your project may involve making digital products available through public or access- controlled websites, kiosks, or live or recorded programs. IMLS expects applicants to ensure that publications produced under an award (including but not limited to peer-reviewed manuscripts resulting from research conducted under an award) are made available in a manner that permits the public to access, read, download, and analyze the work without charge. In your Digital Products Plan, describe how you will make the digital content, resources, assets, software, and metadata available to the public. Include details such as the delivery strategy (e.g., openly available online, available to specified audiences) and underlying hardware/software platforms and infrastructure (e.g., specific digital repository software or leased services, accessibility via standard web browsers, requirements for special software tools to use the content, delivery enabled by IIIF specifications). Identify and explain the reasons for any limitations in your Digital Products Plan.

The accessible makerspace guidelines and accessible maker education curricula will be given a Creative Commons License CC BY-SA, attribution and share alike. The paper will be available free of payment through the University of Illinois open access repository, IDEALS https://www.ideals.illinois.edu. All the digital outputs will meet the Web Content Accessibility Guidelines (WCAG) version 2.1 AA compliance level for its universal access for people with and without dis/abilities.

Access

What rights will you assert over your digital products, and what limitations, if any, will you place on their use? Will your products implicate privacy concerns or cultural sensitivities, and if so, how will you address them? Grant recipients may copyright any work that is subject to copyright and that was

developed under an award or for which ownership was purchased. However, IMLS reserves, for Federal Government purposes, a royalty-free, nonexclusive, and irrevocable right to reproduce, publish, or otherwise use the work and authorize others to reproduce, publish, or otherwise use the work. IMLS expects applicants receiving federal funds for developing or creating digital products to release these files under open-source licenses to maximize access and promote reuse. All work products resulting from IMLS funding should be distributed for free or at cost unless IMLS has provided written approval for another arrangement. In your Digital Products Plan, identify any licenses under which digital products will be shared (e.g., Creative Commons licenses, RightsStatements.org statements). Describe what intellectual property rights you will assert over your digital products and explain any limitations or conditions you will place on their use. If your products implicate privacy concerns or cultural sensitivities, describe these issues and how you plan to address them.

The authors of the accessible makerspace guidelines and accessible maker education curricula will hold the copyright and the paper will be posted to IDEALS https://www.ideals.illinois.edu/, the University of Illinois open access repository. use governed by the CC BY-SA license and will not have any access restrictions. Research interview data we generate will be governed by Institutional Research Board approval, gathered under a formal consent process, and stored under IRB-approved UIUC Box digital storage. Research interviews will be confidential materials used internally for the accessible makerspace guidelines and making curricula, and will not be released beyond the project team.

Sustainability

How will you address the sustainability of your digital products? To the maximum extent possible, the digital products created with IMLS funding should be freely and readily available for use and reuse by libraries, archives, museums, and the public. Some digital products that are generated during a project should be long-lived, requiring permanent preservation, and others (e.g., preliminary analyses, drafts of papers, plans for future work, peer- review assessments, most social media communications, and communications with colleagues) should be retained and shared in the medium- or short-term. In your Digital Products Plan, describe your plan for preserving and maintaining digital products during and after the period of performance and identify the appropriate length of time different digital products should be curated. Address storage systems, shared repositories, technical documentation, migration planning, and commitment of organizational funding for these purposes.

This is part of the of the IDEALS metadata policy and uses the Open Archives Initiative Protocol for Metadata Harvesting (http://www.ideals.illinois.edu/dspace-oai/request?verb=Identify) IDEALS has a Metadata policy available here: https://wiki.illinois.edu/wiki/display/IDEALS/Metadata+Policy. It uses the Dublin Core structure and has some controlled vocabulary.

Data Management Plan

Data sharing is an essential component of research and expedites the translation of research results into new knowledge and practices. Applications for projects that involve the collection and analysis of data must include a Data Management Plan that provides for long-term preservation of and access to the project research data. IMLS expects awardees to deposit data resulting from IMLS-funded research in a broadly accessible repository that allows the public to use the data without charge no later than the date upon which an awardee submits the final performance report to IMLS. The data should be deposited in a machine- readable, non-proprietary digital format to maximize search, retrieval, and analysis. Project budgets may include the costs of preparing the data for public release and for making the data publicly available. In their final performance reports, awardees are required to identify where the data has been deposited and can be accessed by the public. IMLS recognizes that in some cases data sharing may be complicated or limited by institutional policies; local Institutional Review Board (IRB) rules; and local, state, and federal laws and regulations, including those protecting confidentiality and personal privacy. The rights and privacy of people who participate in IMLS-supported research must be protected at all times. Thus, data intended for broader use should be free of anything that could lead to disclosure of the identity of individual participants. Each applicant should identify and explain the reasons for any limitations in their Data Management Plan.

Explain how you will manage, share, preserve, document, and enable reuse of the data you will collect or generate during the project by addressing the following.

- Identify the type(s) and estimated amount of data you plan to collect or generate, and the purpose or intended use(s) to which you expect them to be put. Describe the method(s) you will use, the proposed scope and scale, and the approximate dates or intervals at which you will collect or generate data.

1. Interviews and surveys with ~50 blind and visually impaired (BVI) participants (10 in Phase 2; 40 in Phase 3) will generate recordings and transcripts. Qualitative coding of the interview transcripts will be used for the purpose of generating and refining an accessible makerspace guidelines and maker education curricula. The transcriptionist will sign a confidentiality agreement.

2. Interviews and surveys with ~10 Fab Lab professionals (Phase 1-2), ~10 iSchool students (Phase 1-2), and ~10 librarians (Phase 3) who will directly work with the BVI learners and/or receive training on makerspace accessibility. The interviews will also generate recordings and transcripts.

- Will you collect any sensitive information? This may include personally identifiable information (PII), confidential information (e.g., trade secrets), or proprietary information. If so, detail the specific steps you will take to protect the information while you prepare it for public release (e.g., anonymizing individual identifiers, data aggregation). If the data will not be released publicly, explain why the data cannot be shared due to the protection of privacy, confidentiality, security, intellectual property, and other rights or requirements.

The research activity requires IRB approval. It has not been approved. If the grant is received, University of Illinois IRB approval will be secured. Full interview transcripts will not be shared in order to protect the privacy of our interviewees, and to promote frank discussions with interviewees. For those participants that choose confidentiality on their consent form, any transcripts or recordings will be kept using a code system for identification. The written interviews/surveys notes will be maintained in a secure file cabinet. The typewritten interview

notes, audio recordings, typewritten transcripts, and digital documents will be stored on a password protected hard drive.

- What technical (hardware and/or software) requirements or dependencies would be necessary for understanding retrieving, displaying, processing, or otherwise reusing the data? How can these tools be accessed (e.g., open-source and freely available, commercially available, available from your research team)?

Aside from commonly used office software (e.g. Microsoft Office, Zoom), the only proprietary software we anticipate using for qualitative data analysis is Dedoose, which supports MSAA (Microsoft Active Accessibility) for screen readers. We will also use open-source statistical-computing R environment for both qualitative and quantitative analyses, which can offer great accessibility between researchers with and without dis/abilities.

- What documentation (e.g., consent agreements, data documentation, codebooks, metadata, and analytical and procedural information) will you capture or create along with the data? Where will the documentation be stored and in what format(s)? How will you permanently associate and manage the documentation with the data it describes to enable future reuse?

In-process materials will be stored in Illinois Box for the use of the team. The interview will be recorded and transcribed. There will also be a note taker. The dataset (i.e., transcriptions of the interviews) will not be publicly available.

- What is your plan for managing, disseminating, and preserving data after the completion of the award-funded project? If relevant, identify the repository where you will deposit your data. When and for how long will data be made available to other users?

Interviewee recordings and transcripts are governed by the IRB. They are not intended for dissemination or for long-term preservation beyond the award period. The codebook will be stored on a password-protected hard drive. The documentation will not be permanently managed as the dataset will not be publicly available.

- When and how frequently will you review your Data Management Plan? How will the implementation be monitored?

A valid Data Management Plan may include only the statement that no detailed plan is needed if the statement is accompanied by a clear justification.

The PI and co-PI will review this data management plan at the start of the project and annually during the award period. We also periodically update digital data manage storage passwords.

Organizational Profile
University of Illinois at Urbana-Champaign and the School of Information Sciences

Since its founding in 1867, the **University of Illinois at Urbana-Champaign (Illinois)** has earned a reputation as a world-class leader in research, teaching, and public engagement. With a wealth of resources and highly ranked departments, Illinois long has been recognized for accomplishments in research and graduate education, and is among the top five universities in number of earned doctorates awarded annually in the United States.

Dr. Seo and Dr. Koh's home institutional unit, the **School of Information Sciences (iSchool)**, is a world leader in information science education, research, and practice, and consistently ranks as one of the best in the field. Much of this strength lies in the interdisciplinary expertise of the core faculty, who engage in work across more than forty broad-reaching research areas, including: community informatics; data curation; design & evaluation of information systems and services; digital libraries; information literacy, practices, & behaviors; information retrieval; libraries & librarianship; social and information networks; youth services, and others.

This interdisciplinary foundation, in turn, attracts a talented, diverse cohort of students at both graduate and doctoral levels. The iSchool currently offers 6 distinct degree programs, including the oldest LIS doctoral program in the country and 3 advanced certificate and licensure programs, all supported by an award-winning online education program. The iSchool is currently home to more than 870 graduate and doctoral students, and its population will only grow as it has initiated a new undergraduate degree program in Fall 2020.

As part of its engagement, the iSchool's researchers collaborate on interdisciplinary projects with scholars across our campus, including the University Library, and our local community, including local public and school libraries, as well as institutions across the country and around the world. Local collaboration allows the iSchool to serve the Champaign-Urbana community and surrounding areas beyond the university itself. This service area includes the combined population of Champaign-Urbana, plus nearby small towns, and rural communities, (total population: approx. 230,000).