



Using Design of Location-Based Augmented Reality Experiences to Engage Art-Oriented Girls in Technology and Science

Cathlyn Merritt Davis^{1*}, Amy Kamarainen², Martin Storksdieck³, David Gagnon⁴, Ruth Kermish-Allen⁵ and Kelly Riedinger³

¹Appalachian Laboratory, University of Maryland Center for Environmental Science, Frostburg, MD, United States, ²Harvard Graduate School of Education, Harvard University, Cambridge, MA, United States, ³STEM Research Center, Oregon State University, Corvallis, OR, United States, ⁴Wisconsin Center for Education Research, University of Wisconsin, Madison, WI, United States, ⁵Maine Mathematics and Science Alliance, Augusta, ME, United States

OPEN ACCESS

Edited by:

Michail Kalogiannakis,
University of Crete, Greece

Reviewed by:

Emmanuel Fokides,
University of the Aegean, Greece
Nancy Rodriguez,
UMR5506 Laboratoire d'Informatique,
de Robotique et de Microélectronique
de Montpellier (LIRMM), France

*Correspondence:

Cathlyn Merritt Davis
cathlyn.davis@umces.edu

Specialty section:

This article was submitted to
Digital Learning Innovations,
a section of the journal
Frontiers in Education

Received: 01 April 2021

Accepted: 20 September 2021

Published: 08 November 2021

Citation:

Davis CM, Kamarainen A,
Storksdieck M, Gagnon D,
Kermish-Allen R and Riedinger K
(2021) Using Design of Location-
Based Augmented Reality Experiences
to Engage Art-Oriented Girls in
Technology and Science.
Front. Educ. 6:689512.
doi: 10.3389/feduc.2021.689512

Taking part in creating location-based augmented reality (LBAR) experiences that focus on communication, art and design could serve as an entry point for art-oriented girls and young women towards career pathways in computer science and information communication technology. This conceptual paper presents our theory-based approach and subsequent application, as well as lessons learned informed by team discussions and reflections. We built an LBAR program entitled AR Girls on four foundational principles: stealth science (embedding science in familiar appealing experiences), place-based education (situating learning in one's own community), non-hierarchical design (collaborations where both adults and youth generate content), and learning through design (engaging in design, not just play). To translate these principles into practice, we centered the program around the theme of art by forming partnerships with small community art organizations and positioning LBAR as an art-based communication medium. We found that LBAR lends itself to an interdisciplinary approach that blends technology, art, science and communication. We believe our approach helped girls make connections to their existing interests and build soft skills such as leadership and interpersonal communication as they designed local environmentally-focused LBAR walking tours. Our "use-modify-create" approach provided first-hand experiences with the AR software early on, and thus supported the girls and their art educators in designing and showcasing their walking tours. Unfortunately, the four foundational principles introduced considerable complexity to AR Girls, which impacted recruitment and retention, and at times overwhelmed the art educators who co-led the program. To position AR Girls for long-term success, we simplified the program approach and implementation, including switching to a more user-friendly AR software; reducing logistical challenges of location-based design and play; narrowing the topic addressed by the girls design; and making the involvement of community partners optional. Overall, our initial work was instrumental in understanding how to translate theoretical considerations for learning in out-of-school settings into an LBAR program aimed at achieving multiple complementary outcomes for participating girls. Ultimately, we achieved

better scalability by simplifying AR Girls both conceptually and practically. The lessons learned from AR Girls can inform others using LBAR for education and youth development programming.

Keywords: stealth science, place-based education, learning through design, non-hierarchical design, art, community art organization, environmental issues, design-based learning

INTRODUCTION

Digital media are changing the ways science is accessed, communicated and understood by the public (Brossard, 2013; Brossard and Scheufele, 2013). These media include location-based augmented reality (LBAR), which involves blending the digital and physical worlds. Effective design and application of LBAR focused on science topics requires integration of multiple perspectives and expertise from designers, scientists, community members and others.

Involvement of girls and young women in the design of science-based LBAR “experiences” could help address the ongoing low representation of females in computer science and information communication technology (NSB, 2018; note that we use the term “experiences” throughout this article to describe LBARs created by designers). Specifically, creating science-based LBAR experiences that focus on communication, art and design could serve as an entry point for girls who often have higher levels of interest in language, history and art than in science, computer science, or math (Harvey, 1984; Lazarides and Lauerma, 2019). To be successful, such undertakings must ensure the LBAR design process and product are perceived as interesting and useful to the girls (Vekiri, 2013), and fit with their developing sense of identity (Barton et al., 2012). Furthermore, alignment with identity and possible future career pathways requires a multi-faceted support system that helps girls develop competence, broadens their views of what science and design entails, and provides space for them to explore their own interests and identities.

To examine the utility of LBAR as an entry point into technology identities and careers, we created the AR Girls program, which engages art-oriented girls in technology and science in an innovative way that builds from theory and connects to their own lives. Specifically, we supported girls in designing their own LBAR experiences to communicate about science *via* local environmental issues. As an informal out-of-school program, AR Girls operates through partnerships with small community art education organizations who collaborated with us to initially co-lead this digital art program and ultimately sustain the implementation on their own. During the first 2 years, 45 pre-teen and teen girls aged 11 to 17 participated at three Maine-based organizations, where, with support from our team, art educators and local science professionals, they co-created LBAR “walking tours” using the free open-source *Augmented Reality Interactive Storytelling (ARIS)* software. Their LBAR walking tours centered on communicating environmental issues in their community. The program took place over 2 weeks in the summer (in-person) and then weekly to monthly in the fall (in-person and virtual); it culminated with

girls showcasing their final products at a community event and being encouraged to reflect on impacts on their audiences and themselves.

In this conceptual paper, we present a theory-based approach and subsequent application, which centers on using LBAR as an interdisciplinary avenue to integrate technology, art, science and communication. Specifically, we outline the foundational principles that informed the creation of the AR Girls program, and describe how we translated these to support girls’ co-design of their own LBAR experiences. Informed by discussions and reflections of our design team, we also offer initial lessons learned and associated examples of this case that can guide other programs aimed at engaging youth in collaborative LBAR design.

THEORETICAL BASIS AND APPLICATION OF THE AR GIRLS APPROACH

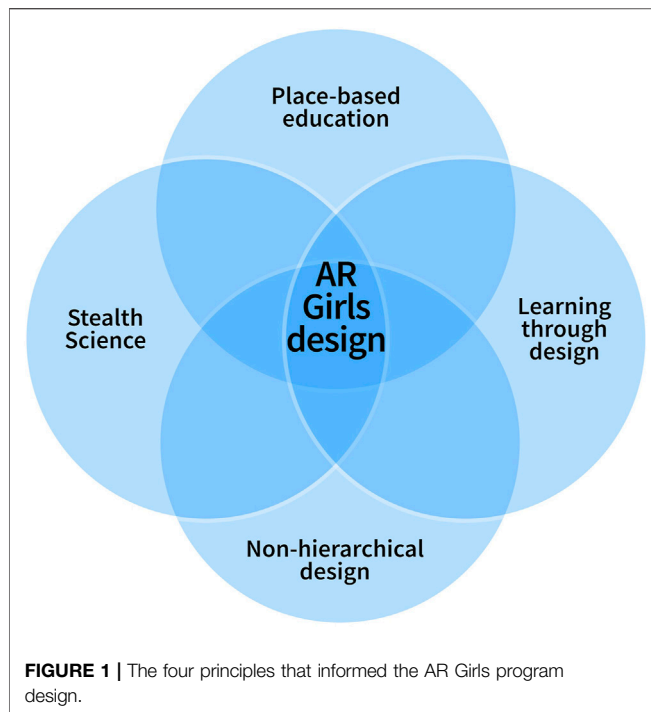
Four foundational principles informed our AR Girls program to support youth creation of LBAR experiences around communication of local environmental issues (Figure 1). In the following sections, we describe each principle and how we applied it within the program.

Stealth Science Description

Stealth science offers an avenue to expand audience participation by embedding interactions with scientists and science content into familiar experiences that appeal to participants who would not self-select to engage in more traditional science learning opportunities (Barron, 2006; Miller, 2010). For example, science-based discussions of musical instruments or art techniques could be integrated into music and art festivals. Stealth science builds on the premise that programs integrated into familiar and comfortable culturally-rich or leisure-time settings support positive affective orientations, and can create positive science experiences for culturally oriented but science-disinterested people (Linnett, Durant, Levenson and Wiehe, 2014; Storksdieck, Styliniski and Bailey, 2016; O’Connell, Keys, Storksdieck and Rosin, 2020).

Application

For the AR Girls program, we were explicitly interested in attracting girls who shared an inclination towards art but had diverse orientations toward science and technology. Given these possible divergent motivations, we approached science somewhat indirectly and through the lens of relevance and personal significance by centering the LBAR experiences on environmental issues in the girls’ own communities. Many of



these issues require consideration of scientific aspects within a social context, and thus lend themselves to an interdisciplinary viewpoint that can bring together science, communication and art *via* LBAR. That is, rather than targeting more traditional science inquiry activities such as data collection, we embraced communication as an activity that is a component of the practice of science (NRC, 2012a). As such, we used community-based environmental issues as the topic, digital art-based LBAR as the medium, and science communication as the practice. We provided some simple planning guidance on effective science communication that had girls address the following questions as they developed their LBAR experiences:

- What do you want to communicate about the environmental issue (i.e., what is your communication goal)?
- How will you use LBAR to communicate this?
- Who is the audience of your LBAR experiences?
- After sharing the LBAR experiences, how will you gather audience feedback to determine if you achieved your communication goals?

We promoted the girls' understanding of scientific aspects of the environmental issues by recruiting and involving local science professionals (e.g., natural resource managers and consultants) in the AR Girls program. To avoid the perception among our art-oriented participants that science was the focus, we simply referred to these professionals as "community partners," and described them as a resource to help the girls plan and design their LBAR experiences. We gave girls autonomy in selecting their specific environmental issue (e.g., climate change, water quality, plastic pollution) with the community partners

promoting consideration of robust science content by providing ideas, answering questions, and suggesting relevant resources.

Finally, from the perspective of stealth science, we used several strategies to firmly situate AR Girls and LBAR design within the context of art. First, we formed collaborations with small community art education organizations already serving local youth and maintaining trained staff and a diversity of art supplies. We recruited girls through these organizations with flyers framing the program as art-focused, hosted girls at their facilities, and partnered with their staff to plan and co-lead the AR Girls activities. Second, we infused art-based design and communication activities throughout the program. For example, we led girls in producing a collage with QR codes, creating a personal avatar, and learning skills in digital photography. Third, we encouraged girls to produce original artwork that could be integrated into their LBAR experiences. To support this work, we provided relevant mini-tutorials (called "power ups") such as using *Sketchbook* to draw digital characters, *iMovie* to edit videos, and *Media in ARIS* to upload media in appropriate digital dimensions and formats.

The two examples below provide insight into how this interdisciplinary/stealth science approach worked within the AR Girls program, and how the associated activities provided opportunities for the girls to express their interests and gain new skills.

Jasmine, Annie, Zena and Wanda formed a team after expressing mutual interest in the lobster fishery. Jasmine had prior digital drawing experience using *Sketchbook* and shared some of these skills with her teammates; Wanda self-identified as a writer and described herself using words like "sensitive" and "creative"; Annie expressed an interest in music and basketball, while Zena stated her interest in fashion. With staff support, this diverse team combined their interests by creating an LBAR-based experience about changes in the lobster fishery off the coast of Maine. As the team developed their ideas and moved from the brainstorming phase to the production phase, Jasmine took on a leadership role guiding the creative direction of the project, providing original artwork for some of the characters, and contributing to the programming. Wanda took on character development, and offered to lead writing dialog for the characters. Annie gravitated toward researching content for the experience, and also edited the video interviews they had collected from their community partner. Finally, Zena supported both the game design and led the programming and debugging. By the end of the 2 weeks, the girls had developed different skills and a distinct identity aligned to their role in the team. For example, Jasmine earned "power-up" badges for gaining proficiency in *Sketchbook*, programming and drawing, and characters and conversations, while Annie completed self-directed training on transcoding and editing video, and integrating media into the AR software. After completing the AR Girls program, Wanda expressed high satisfaction because, "I learned how to digitally draw!"

Mel and Dana were friends who joined the AR Girls program together. Dana had skills in traditional and digital sketching, while Mel described herself as a singer, actress, and gymnast. Both



FIGURE 2 | An example of the girls' original artwork, which was overlaid on a photograph and used for one of their "stops" in their AR walking tour.

helped create a recycling program at their middle school. Building on these interests and prior experiences, the pair decided their communication goal was to encourage others to reduce waste in order to address the issue of plastic pollution in the ocean. They planned an LBAR experience that used their own original artwork coupled with strategies to avoid single-use plastics. They made connections to their community by overlaying this artwork on photos of different locations in their town (**Figure 2**), and used these images within their LBAR experience.

Place-Based Education Description

Place-based education situates learning in the context of one's own community, and thus aligns with interdisciplinary learning and environmental issue investigations, as well as socioscientific orientation (Herman et al., in press). Specifically, positioning learning in a place leverages the local environment and community as an asset, and allows learners to explore local phenomena that are relevant to them (Sobel, 2005). From the perspective of place-based education, LBAR can guide learners in investigating and observing these phenomena in ways that incorporate location-specific people, places, language, and artifacts, and thus center learning around culturally-relevant issues and topics (Dede, 2009; Ahlqvist and Schlieder, 2018).

Locally-based LBAR experiences integrate learner's prior knowledge and personal experiences of place. Overall, place-based design pursuits can bolster confidence with regard to influencing positive community change, which in turn can produce stronger learning outcomes (Sobel, 2005; Gruenewald and Smith, 2008; Smith and Sobel, 2010).

Application

We applied place-based education by centering the AR Girls program on the local community and associated environmental issues, and guided the girls and their community partners in constructing LBARs focused on their region. As part of a co-design workshop in the first week of the program, the girls and their community partners discussed and mapped community assets and features related to their selected environmental issue. From these brainstorm sessions, the girls and partners answered the four communication questions (see *Stealth Science Application* section), including determining their communication goals and how they would use LBAR to achieve these. By positioning themselves as AR designers, the girls made decisions about connections between geospatial and other attributes, and, as described earlier, if and where to integrate their own artwork (sketches, photos, animations, and video clips) in their LBAR experiences.

For example, AR experiences can take on a variety of formats including games, choose-your-own-adventure stories, character-driven narratives, and scavenger hunts. To align with our place-based education approach, we selected "walking tour" as the primary format because it combines elements of other types, and places the player directly in the community as they explore the selected environmental issue. Additionally, walking tours are an intuitive format for both the youth and adults, many of whom had no prior experience with AR. While some girls characterized their work as a "game," all ultimately produced community-based LBAR walking tours to communicate their environmental issue.

For example, Erin, Heather, Ally and Laura worked with a community partner who had a background in civil engineering and brought in large maps that delineated the watershed for their community. After the co-design workshop, the girls created a walking tour to show issues related to stormwater runoff and drainage. Their tour included stops that highlighted problem areas in their town such as a street that funnels rain runoff directly into a nearby stream.

Non-Hierarchical Design Description

In non-hierarchical design, a collaborative learning environment is formed in which adults (e.g., educators, scientists, professionals) are not perceived as the sole owners of knowledge; instead, all users are both generators of content and active learners, and the boundaries between educators and youth, scientist and citizen and young and old are blurred into one cohesive community of actively engaged science learners (Kermish-Allen, 2015). These learning environments can lead to an enhanced sense of youth "buy-in" and an increased level of youth empowerment, resulting in a shift in interpersonal dynamics as adults discover the wealth of knowledge and

resources that youth bring to the table (Barton and Tan, 2009). When combined with place-based education, non-hierarchical learning posits that 1) all community residents, including youth, are important resources, and 2) teams of young and old participants should address questions and issues that are relevant to the community (Kermish-Allen et al., 2015). Such collaborative work mirrors the authentic practice of typical multi-disciplinary LBAR teams.

Application

From the perspective of non-hierarchical design, we formed teams of girls with one or two community partners (the science professionals mentioned earlier section), and we honored the knowledge and skills that both girls and their adult partners brought to the program. Specifically, the adults were framed as experts in environmental topics while the girls were situated as experts in new and creative ways to communicate about these issues *via* LBAR. We encouraged girls and adults to share insight around local environmental issues during the process of selecting a topic of interest and while mapping out their communication plan.

To establish and maintain a collaborative and non-hierarchical atmosphere, the community partners were invited into the space where the girls had been meeting throughout the first summer week and to participate in AR Girls daily rituals including icebreaker games and lunch. As the LBAR experts, the girls introduced their adult partners to LBAR and its capabilities *via* mini walking tours (created during a prior training session). *Via* the community asset activity (mentioned earlier section), the teams then collaboratively discussed how to best address their environment issue both in terms of science aspects (guided by community partners) and communication aspects (guided by the girls). After outlining their LBAR tours, girls did the production work while their community partner(s) provided feedback and guidance on the science and the emerging products. This is illustrated in the following example. Alyse, Meredith and Lynn met with Trevor from the local watershed coalition. He asked the girls to help him communicate about how bioassessment can be used to understand the health of a stream. During the non-hierarchical co-design workshop, Trevor shared information about the relationship between water quality and macroinvertebrate species along with his own sketch of a mayfly larva. The girls used this understanding to develop their walking tour, and colorized his sketch and incorporated it as a character in their tour.

Learning by Design

Description

Research suggests that young people learn science concepts more deeply when they engage in the design, not just the play, of digital media (Kafai, 2009; NRC, 2011). Indeed, learning by design approaches have been shown to support multiple facets of learning including motivation (Vos et al., 2011), content understanding (Doppelt et al., 2008; Honey and Kanter, 2013), and engagement (Doppelt et al., 2008; Honey and Kanter, 2013; Fisher et al., 2014). Learning by design can situate LBAR production in the interdisciplinary and authentic space of

one's own community, which, in the context of AR Girls, can engage participants in the practices of computational thinking and science (e.g., Litts, Lewis and Mortensen, 2020). Searle et al., 2018 found that, given an opportunity to apply knowledge to real situations, LBAR design work can empower youth to take ownership of their own learning, and may motivate youth not necessarily oriented toward digital technologies to embrace them as productivity tools. Finally, learning by design typically embraces collaborative work, and thus can be interwoven with the non-hierarchical design aspect of AR Girls, and, as such, can promote associated 21st Century Skills (NRC, 2012b) such as communication and teamwork (Kolodner et al., 2003; Fisher et al., 2014).

To be effective, a learning by design approach should include several key aspects. Learners must be supported in the transition from passively receiving instructions and carrying out defined tasks to becoming active creators of content and media through a sometimes messy and collaborative design process (Bower et al., 2014). They should also consider players of their design products (Bower et al., 2014; Searle et al., 2018). Finally, instructors may need to be experienced in a broader range of pedagogical approaches and understand that diverse and learner-driven outcomes are to be expected (Neville, 2010).

Application

To support learning by design, we used the *ARIS* platform (Gagnon, 2010; Holden et al., 2014) as it offers extensive functionality for creation of LBAR experiences. Developed at the University of Wisconsin, *ARIS* is a “free and open-source platform for creating location-based interactive games, stories and tours” (*ARIS*, 2016). As software, it contains two parts, 1) an online HTML5-based authoring tool that is used to design and create content and 2) a separate mobile app that is used by the players to experience the content. The software is organized around scenes, conversations, characters, events and quests as the primary design tools. These elements are linked together in sequences, and managed by designer-defined game logic, allowing the creation of simple simulations and games that respond to the user's choices. Physical, GPS-based position, as well as virtual position (using QR codes or the location of an avatar on a map), orients the story around real-world locations—in the case of AR Girls, these locations were based in Maine (**Figure 3**). *ARIS* support is primarily provided through an online user community, though some of the *ARIS* creators were able to offer supplemental support to AR Girls participants.

To support novices in designing LBAR using the feature-rich *ARIS* software, we drew from the “use-modify-create” approach (Lee et al., 2011), which is outlined below.

- **Use:** On the first day of AR Girls, the participants played two pre-produced introductory LBAR walking tours, which had been custom designed for the outdoor spaces near their art education organization. One was created by our team and modeled the “walking tour” format described earlier, while the other was created by the resident art educators and varied depending on their interests. These LBARs introduced girls to basic *ARIS* features including

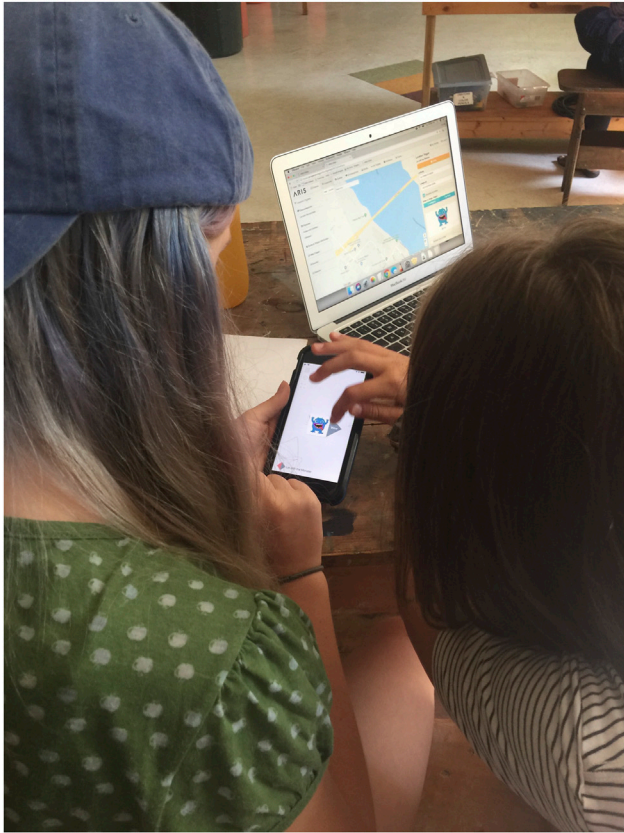


FIGURE 3 | Girls use a computer and mobile device to test their LBAR walking tour, which includes their original artwork.



FIGURE 4 | An example of one of the girls' "talent trees" with paper badges of completed "power-ups" and teamwork awards.

location-based and QR-code based activation, choice-based branching dialog, receiving items, and embedding audio and video clips.

- **Modify:** After this initial play time, the girls shifted to the designer role. First, we unpacked how ARIS was used to create the pre-produced walking tour. Then, working in pairs, the girls modified one of these tours by adding a "stop" (a new location on the tour). This gave them a hands-on, simple and scaffolded learning opportunity to build their own tours with ARIS.
- **Create:** The girls spent the remainder of the program in the "create" phase, which consisted of ideation, designing, programming, playing, testing, and revising their own LBAR walking tour.

Our team (including the art educator) remained available throughout the design process to answer questions and support the girls' independent projects. We also developed a "just-in-time" resource to encourage girls to expand their existing skills and to promote self-directed learning of LBAR design. This consisted of optional "power-ups," which were short, self-guided tutorials on select technical components of ARIS and other related media tools. We eventually added access to the full ARIS manual, and made all these resources available online.

We attempted to connect the optional power-ups with a badging system in which girls earned paper badges after completing self-selected power-ups, and awarded badges to each other for accomplishments associated with teamwork. These were posted on large paper "Talent Trees", which were drawn by the girls and visually displayed their growing library of skills related to LBAR (Figure 4).

From the beginning, we had girls prepare their LBAR walking tours for use by family, friends and their community partners at a fall showcase event. The girls planned the event structure in which they shared their production process, had attendees play their LBAR walking tours, and collected audience feedback using a simple questionnaire. We helped the girls reflect on audience impacts from these completed questionnaires in context of their targeted communication goals.

LESSONS LEARNED

Our AR Girls program team consisted of nine experienced professionals from different disciplinary backgrounds: educators, media specialists, and education/learning researchers who had varied roles including design, implementation, and evaluation. Some of the team members

worked shoulder-to-shoulder with the local art educators during the implementation of the program. At the end of each day, this team would gather girls' feedback, and later briefly discuss their own reflections on the day's events and girls' responses. Our whole design team also met to share our diverse perspectives and reflect on the implementation with the girls, community partners and art educators in context of our four foundational principles and our expertise. From these conversations, we identified key design lessons with regard to applying theory to practice in the context of 1) supporting youth in designing LBAR, 2) pursuing an interdisciplinary approach that integrates technology, art, science, and communication, and 3) focusing on place-based education. Below we outline each lesson with special attention on supporting our informal education partners in ongoing independent implementation.

Design to Support Youth-Driven Location-Based Augmented Reality Design

As noted, we sought to engage our girl participants in interest-driven participatory design of their own LBAR experiences, and used three strategies to support this design work: the use-modify-create approach, "power-up" tutorials, and co-designing with adult stakeholders.

First, our reflections on the implementation suggest that the use-modify-create approach can be an effective way to frame and support an introduction to the technology for both girls and art educators. As an example, we found that, after playing the pre-produced introductory tours ("use" activity), girls quickly understood the concept of "adding a stop" to these existing location-based walking tours ("modify" activity). Likewise, they seemed well-prepared to apply multiple aspects of *ARIS*' functionality as they transitioned to the "create" phase as exemplified below.

When Patty, Laurie, Jane and Rachel modified the experience created by the art educator, they added their own character to the story and tried using the branching dialog feature. They made mistakes but easily troubleshot and fixed the problem, ultimately producing a playable activity. They applied this knowledge of branching dialog when they later designed and produced their own tour.

The scaffolded use-modify-create approach to the *ARIS* platform meant that girls entered the design process quickly and without the need for additional instruction from the art educator. This was critical as our educators were LBAR novices, and thus were building their own skills and confidence alongside the girls. We helped these educators gain their own hands-on and in-depth experience with *ARIS* by producing one of the two introductory experiences prior to the start of the program. During this pre-program training period, our team offered extensive guidance in a way that was designed to be fun and engaging, while building the art educators' skills and confidence in LBAR.

Second, we offered the power-up tutorials to give the girls autonomy to determine which technological skills would be useful for their LBAR production work, while the associated badging system offered a visual display of their growing expertise. Some girls seemed to enjoy collecting the badges but several asked

questions that illustrated their confusion over which power-ups were necessary for their work, and some complained to us that the tutorial instruction was long-winded. We had envisioned the power-ups and associated badging system as a self-directed activity, but the girls sought regular guidance, and our team and the art educators had to divert attention to manage this program aspect as described in the following example. Annie was idle at her work station; when questioned, she reported she was waiting for the art educator to check that she had completed her power-up tutorial so she could receive her badge.

Thus, the badging became a bottleneck in the workflow and a distraction, as some girls focused on the badges rather than the design of their LBAR walking tour. We dropped the badging system, and, after refinements, moved the power-up tutorials to a simple website with short videos and links to external resources, including the complete *ARIS* manual. However, even with these improvements, the girls continued to rely on the art staff to answer technical questions that were often beyond these educators' expertise. Given the complexity of LBAR development within the *ARIS* system, the girls needed more experienced facilitators who could address issues, provide feedback and overall build their confidence in using this tool.

Finally, our team reflections indicate that approaching LBAR as a collaborative experience can infuse robust science content into design *via* involvement of knowledgeable community partners. The girls accessed these local science professionals as resources in three distinct ways that were not foreseen by our team: 1) as partners with an equal voice in defining the theme and approach of the LBAR walking tours; 2) as advisors who guided but did not drive the direction of the tours; and 3) as clients who had specific needs that the girls sought to address. Like other work on interest-driven design (Rahimi and Kim 2019), these partnerships appeared to allow some girls to see themselves in roles that they never imagined before (e.g., Jasmine declared, "I didn't know I had leadership skills"). Additionally, some girls seemed to appreciate the science perspectives offered by their community partners, and seriously considered how to incorporate these into their LBAR walking tours. But, others seemed to feel constrained by their community partner's take on the environmental theme and the lack of freedom to follow their interests, and some developed storylines in which their creativity was at odds with the scientific communication goals of their tours. For example, Felicity, Morgan, and Helen developed a very complex and creative storyline involving fairies, warlocks, demons and Danny DeVito. While this story had funny and engaging dialog and a dizzying game logic, it only loosely tied to the environmental theme and did not relate specifically to the community or local context in which it was played.

Additionally, although the community partners were tremendously engaged (e.g., they attended and fully participated in all sessions), their involvement required that we commit considerable time towards communication, coordination and orientation to prepare them prior to their participation. Beyond the funding window, this task would shift to the art educators (including possibly recruiting and preparing replacement partners), thus compromising sustainability of the program.

Designing for an Interdisciplinary Approach of Location-Based Augmented Reality

Our theoretically-driven approach intentionally blended technology, art, science and communication, and, as designers, we found that LBAR provided an ideal avenue to weave these diverse disciplinary themes together. First, while not typically characterized as an art form, LBAR offers tremendous opportunities for creativity. As noted, it can be used for storytelling, gaming, narrated tours, hybrid-world explorations and more, while integrating diverse art elements including audio, drawings, animations, live action video, and natural and synthetic sounds. With its focus on interaction, LBAR also serves as an innovative communication medium to engage audiences on any number of topics. Thus, our AR Girls participants could draw from multiple disciplines as they created their LBAR walking tours on locally-relevant environmental issues. We believe this broader perspective also allowed girls to engage in the design process in ways that aligned with their interests and skills, as illustrated in the following example. Patty, Laurie, Jane and Rachel designed a fitness-focused LBAR walking tour based at a local playground that built on their shared interests. Patty and Rachel were accomplished artists and had existing characters that they liked to draw; they incorporated versions of these characters into their game. Meanwhile Jane and Laurie were both involved in sports, Jane focusing on cheerleading and gymnastics, while Laurie was into hockey. They researched information about fitness and health, which they incorporated into their tour.

Furthermore, within our design, we embedded opportunities for the girls to improve and reflect on multiple 21st Century Skills (commonly referred to as “soft skills”), such as leadership, collaboration, interpersonal communication and time management (NRC 2012b). As highlighted in the below example, girls could recognize one another for teamwork skills using pre-printed badges. For example, Zena received a badge from her teammates for being a “project manager” and “time keeper” as she helped maintain the focus on the big picture in mind and reminded her teammates of deadlines and remaining time. Ella received a badge for “being an awesome teammate”, who supported her team through various playtesting and debugging challenges.

The interdisciplinary approach of this program required managing a multifaceted suite of pedagogical skills related to technological ability, science content, communication approaches, and digital art strategies *via* websites, power-ups, community partners, guiding templates, and more. Our diverse team of educators and media specialists brought the necessary expertise and preparation to leverage these resources and address the girls’ needs and questions. Wagler and Mathews (2012) describe other instances of successful facilitation of LBAR design in an interdisciplinary context; however, all of these focused on adult learner-designers. Facilitating interdisciplinary instruction with youth requires an experienced and confident teacher working over extended periods of time with these learners. This need for multi-disciplinary expertise can outmatch the training and

experience of some art educators who often come from diverse career paths (unlike the structured training of K-12 teachers) and do not work at small non-profit community art organizations long enough to gain relevant skills.

Designing for Local and Authentic Audience Experiences

The AR Girls’ LBAR experiences took the form of place-based walking tours, which provided multiple benefits for our youth participants. Framed as such, these environmentally-based design challenges directly built on girls’ pre-existing knowledge of their communities—its geography, landmarks, members, culture, history and more. Anecdotal evidence suggests that this framing helped motivate the girls *via* connections to their interests and daily lives. For example, one girl knew someone who struggled to find mental health resources, and chose to focus her team’s walking tour on the positive effects of music on mental health, orienting it around community sites where the player could play, listen to, or participate in music. Finally, we supported girls in a user-centric design approach. As such, thinking about their “audience” became a powerful theme, and we encouraged girls to consider player’s experience throughout the design process. Specifically, we had them articulate their communication goals and their specific target audience, we provided a community event for them to showcase their final productions, and we supported them in collecting and reflecting on simple evaluations to determine if they impacted their audiences as intended.

However, the local context also presented significant challenges for the girls and the art educators. As girls play-tested and worked on debugging their LBAR walking tours, they discovered a number of limitations associated with time, distance, and access. For instance, while two of our partnering art education organizations were near walkable streets, footpaths, and interesting landmarks, the third was adjacent to a busy pedestrian-unfriendly road and quite distant from the town center, offering few opportunities for location-based activities. Furthermore, at all three sites, girls found that some important local stops could not be used because they were too far for a walking tour, had only limited availability, or could not be safely accessed. Accessibility aside, supervising groups of girls outdoors as they gathered media and programmed their walking tours presented logistical challenges. While manageable with our multi-person team, this task will be onerous for a single art educator lacking additional support.

CONCLUSION AND NEXT STEPS

We built the AR Girls program on the premise that designing interdisciplinary LBAR walking tours that focus on communication, art, and environmental issues could serve as an entry point for girls into computer science and information communication technology career pathways. As noted, such design experiences should embrace and expand girls’ interests, developing sense of identity, self-efficacy around computer science and information communication technology, and their views of science and technology as

components of their future careers. To meet these goals, we crafted the AR Girls program around four theoretically-driven foundational principles—stealth science, place-based education, non-hierarchical design, and learning through design. In translating these principles into practice, we made art the centerpiece by forming partnerships with small community art organizations, positioning LBAR as an art medium, and creating activities that highlighted the potential of art as a powerful tool to communicate about challenging issues.

From our first 2 years of designing and implementing AR Girls, our team concluded that LBAR lends itself to an interdisciplinary approach that blends technology, art, science and communication. Our perception is that AR Girl participants easily embraced LBAR as an art medium and gained some understanding of its potential power as a communication tool. Our interdisciplinary approach allowed them to make connections to their existing interests as they designed their environmentally-focused LBAR walking tours. We believe that having an authentic purpose for their tours (articulated in their communication plans) and being provided the opportunity to showcase and evaluate their final products proved an effective motivator. This aligns with Kafai, Burke and Mote (2012) who found that having youth participate in game design and engage with actual users (a potentially stressful and intimidating experience) can positively affect motivation, while also influencing how designers seek and incorporate honest user feedback.

The use-modify-create approach helped us create activities that could ramp up the girls' understanding of and confidence with the ARIS software, the comprehensive but complex AR platform used in this project. This "inductive" form of learning—concrete example followed by abstraction and transfer to a new but similar context—provided quick hands-on and active engagement, which is a crucial instructional design element of successful out-of-school learning (NRC, 2015). Finally, while some girls seemed to find the collaborations with science professionals cumbersome, for the most part, these partnerships suggest that robust locally-based science content can be embedded into informal education programming without disrupting the focus on art. Additionally, working with these adults and other girls in non-hierarchical ways opened opportunities to build soft skills such as leadership, interpersonal communication, teamwork, and organization. Our reflection agrees with Fisher et al. (2014) who also report that engaging youth in the design process works best when it includes close working relationships with varied stakeholders in the local community.

However, while effective, each of the four foundational principles introduced considerable complexity to the AR Girls program, which interfered with girl recruitment and retention and overwhelmed the art educators. With our grant funding, we were able to commit considerable time and resources to recruit, train, coordinate and support art educators and science professionals, but this limits potential scale-up and sustainability of the program. While both educators and science professionals expressed a strong commitment to remain with the program, turnover is inevitable, and, without our involvement, future versions of the program would lack a process for on-boarding new partners. Furthermore, while the art educators seemed to quickly gain some expertise with the LBAR approach and software, thanks in part to the use-modify-create approach, they

nonetheless expressed feeling daunted by the interdisciplinary aspects of AR Girls, which required understanding of communication, science, design, and various digital media tools. That is, although the AR Girls design embraced multiple theoretical aspects necessary for full program success, the resulting implementation ended up being overly ambitious and challenging for frontline educators. Even the participating girls and their parents voiced confusion over the true focus of the interdisciplinary program, and some girls dropped out in the initial days because they expected a more relaxed and flexible art experience rather than a comprehensive and demanding production process. While the written instructions (e.g., power-ups and ARIS manual) provided some useful guidance for both art educators and their participants, the girls' actions demonstrated that they still needed experienced teachers as problem-solvers to field technological questions and deepen their confidence. Likewise, while the focus on place as a key pedagogical approach and a bounding design constraint connected well to the girls, it presented considerable logistic challenges for art educators who had to address issues that stemmed from working in the community (rather than in the rooms of a local art center). These included accessibility and supervision as the girls went into the community to collect media and test their LBAR walking tours. These outdoor excursions also required maintenance of paid mobile data service plans to program and play the LBAR experiences on mobile devices.

To address these issues and challenges, we made several key revisions to AR Girls in its third year, which we believe will position the program for long-term success. All these changes fit under the theme of simplification. We kept the interdisciplinary focus but narrowed the environmental issues to just one (waste). Our art educators expressed serious reservations about maintaining the partnerships with the science professionals (including recruiting and preparing new partners given inevitable attrition). We responded to these concerns by making this component optional and instead providing robust science content through a newly-created online resource library focused on a single topic related to all communities (excess waste). While digital resources cannot replace the benefits of dialogue and relationship-building with adult community members knowledgeable in the sciences, these resources complemented the online self-directed technical tutorials and provided high-quality, easily accessible, relevant and appropriate background to inform the girls' science-focused LBARs. In addition to this shift in the source of science information, we condensed the delivery of what originally was a multi-month program to only the summer, which better matched art educators' and family schedules. Finally, we switched to another AR platform (*Metaverse*) that has lower barriers to entry and better usability for our purposes. This required considerable rewriting of our program activities and a de-emphasis on local walking tours. That is, rather than having players walk through the community, stopping at various markers, the girls use *Metaverse* to build "markerless" AR experiences in which 2D or 3D digital objects and text are superimposed on the real world in any location. Thus, though not technically "location based," these experiences can still address issues relevant to a specific place *via* various formats but can be played anywhere including within the confines of an art studio. For example, in a pilot implementation with this new software, one girl developed a quiz-based AR

experience that encouraged players to make better personal choices that impact both health and food waste in her community.

The first 2 years of work on AR Girls were instrumental in understanding how to translate theoretical considerations for learning in out-of-school settings into an LBAR program aimed at achieving multiple complementary outcomes for participating girls. However, our approach also provided important lessons on the difference between conceptually desirable and practically possible. Optimizing towards multiple features to achieve several interconnected outcomes led us down a path towards creating a comprehensive but ultimately over-designed LBAR program that exceeded capacities of the informal educators who would maintain this offering. The lessons learned can inform others using LBAR for education and youth development programming, in part by reminding us about an important overall design principle for broad success—keep it simple and focused.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article. Further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

This study involved human participants, and was reviewed and approved by the University of Maryland College Park IRB

REFERENCES

- Ahlqvist, O., and Schlieder, C. (2018). "Introducing Geogames and Geoplay: Characterizing an Emerging Research Field," in *Geogames and Geoplay*. Editors O. Ahlqvist, and C. Schlieder (Cham): Springer, 1–18. doi:10.1007/978-3-319-22774-0_1
- ARIS [Computer Software] (2016). Available at: <http://arisgames.org>.
- Baradaran Rahimi, F., and Kim, B. (2019). The Role of Interest-Driven Participatory Game Design: Considering Design Literacy within a Technology Classroom. *Int. J. Technol. Des. Educ.* 29 (2), 387–404. doi:10.1007/s10798-018-9451-6
- Barron, B. (2006). Interest and Self-Sustained Learning as Catalysts of Development: A Learning Ecology Perspective. *Hum. Develop.* 49, 193–224. doi:10.1159/000094368
- Barton, A. C., Kang, H., Tan, E., O'Neill, T. B., Bautista-Guerra, J., and Brecklin, C. (2012). Crafting a Future in Science Tracing Middle School Girls' Identity Work over Time and Space. *Am. Educ. Res. J.* 50 (1), 37–75. doi:10.3102/0002831212458142
- Barton, A. C., and Tan, E. (2009). Funds of Knowledge and Discourses and Hybrid Space. *J. Res. Sci. Teach.* 46 (1), 50–73. doi:10.1002/tea.20269
- Bower, M., Howe, C., McCredie, N., Robinson, A., and Grover, D. (2014). Augmented Reality in Education - Cases, Places and Potentials. *Educ. Media Int.* 51 (1), 1–15. doi:10.1080/09523987.2014.889400
- Brossard, D. (2013). New media Landscapes and the Science Information Consumer. *Proc. Natl. Acad. Sci. U S A.* 110, Supplement 3, 14096–14101. doi:10.1073/pnas.1212744110
- Brossard, D., and Scheufele, D. A. (2013). Social Science. Science, New media, and the Public. *Science* 339 (6115), 40–41. doi:10.1126/science.1232329
- Dede, C., and Barab, S. (2009). Emerging Technologies for Learning Science: A Time of Rapid Advances. *J. Sci. Educ. Technol.* 18 (4), 301–304. doi:10.1007/s10956-009-9172-4
- (1075529). Written informed consent to participate in this study was provided by the participant and their legal guardian.

AUTHOR CONTRIBUTIONS

All authors contributed to conception and design of the program and associated research. CD and AK wrote the first draft, and CD wrote subsequent drafts, including the final draft. AK, MS, DG, RK-A, and KR read and edited each draft. All authors read and approved the submitted version.

FUNDING

This work was supported by the National Science Foundation under grant numbers DRL-1657317, DRL-1657248, DRL-1657217, and DRL-1657017.

ACKNOWLEDGMENTS

The AR Girls program is a collaborative effort with tremendous support for all team members (co-authors plus Phelan Gallagher, Jenna Linhart, Chris Dede, Gemma Perretta Scott, and Jim Mathews), as well as the art educators and other staff at our three partnering art education organizations. We also thank the young women and local science professionals who participated in the AR Girls program.

- Doppelt, Y., Mehalik, M. M., Schunn, C. D., Silk, E., and Krysiniski, D. (2008). Engagement and Achievements, A Case Study of Design-Based Learning in a Science Context. *J. Technol. Educ.* 19 (2), 22–39.
- Fisher, K. E., Bishop, A. P., Magassa, L., and Fawcett, P. (2014). Action!. *Proc. 2014 Conf. Interaction Des. Child.* 345–348. doi:10.1145/2593968.2610488
- Gagnon, D. (2010). *ARIS, an Open Source Platform for Developing mobile Learning Experiences [Master's Thesis]*. [Madison (WI)]: University of Wisconsin, Madison.
- Gruenewald, D., and Smith, G. (2008). *Place-based Education in the Global Age, Local Diversity*. New York: Lawrence Erlbaum Associates.
- Harvey, T. J. (1984). Gender Differences in Subject Preference and Perception of Subject Importance Among Third Year Secondary School Pupils in Single-sex and Mixed Comprehensive Schools. *Educ. Stud.* 10 (3), 243–253. doi:10.1080/0305569840100305
- Herman, B. C., Zeidler, D. L., and Newton, M. (in press). Impact of place-based socioscientific issues instruction on students' contextualization of socioscientific orientations. *Science Education*. doi:10.1002/scs.21618
- Holden, C. L., Gagnon, D. J., Litts, B. K., and Smith, G. (2014). "Aris," in *Technology Platform Innovations and Forthcoming Trends in Ubiquitous Learning*. Editor M. Mendes (Hershey, PA: IGI Global), 19–34. doi:10.4018/978-1-4666-4542-4.ch002
- Kafai, Y. B., Burke, Q., and Mote, C. (2012). What Makes Competitions Fun to Participate? the Role of Audience for Middle School Game Designers. *Proc. 11th Int. Conf. interaction Des. Child.* 12, 284–287.
- Kafai, Y. B. (2009). *State of Evidence, How Can Games and Simulations Be Used to Increase Science Learning*. Washington, D.C.: National Research Council Workshop on Gaming and Simulations. Available at: http://www7.nationalacademies.org/bose/Kafai_Gaming_Presentation.pdf (Accessed March 23, 2010).
- Kermish-Allen, R., Peterman, K., and MacDonald, S. (2015). Student and Teacher Teams Using High Resolution Electricity Monitoring to Create Local Change. *J. Sustainability Edu.* 8.
- Kolodner, J. L., Camp, P. J., Crismond, D., Fasse, B., Gray, J., Holbrook, J., et al. (2003). Problem-Based Learning Meets Case-Based Reasoning in the Middle-

- School Science Classroom: Putting Learning by Design(tm) into Practice. *J. Learn. Sci.* 12 (4), 495–547. doi:10.1207/s15327809jls1204_2
- Lazarides, R., and Lauermann, F. (2019). Gendered Paths into STEM-Related and Language-Related Careers: Girls' and Boy's Motivational Beliefs and Career Plans in Math and Language Arts. *Front. Psychol.* 10, 1243. doi:10.3389/fpsyg.2019.01243
- Lee, I., Martin, F., Denner, J., Coulter, B., Allan, W., Erickson, J., et al. (2011). Computational Thinking for Youth in Practice. *Acm Inroads* 2 (1), 32–37. doi:10.1145/1929887.1929902
- Linnett, P., Kaiser, D., Durant, J., Levenson, T., and Wiehe, B. (2014). The Evolving Culture of Science Engagement, an Exploratory Initiative of MIT and Culture Kettle - Report of Findings. Available at: <http://www.cultureofscienceengagement.net/> (Accessed March 31, 2021).
- Litts, B. K., Lewis, W. E., and Mortensen, C. K. (2020). Engaging Youth in Computational Thinking Practices through Designing Place-Based mobile Games about Local Issues. *Interactive Learn. Environments* 28 (3), 302–315. doi:10.1080/10494820.2019.1674883
- M. Honey, and D. E. Kanter (Editors) (2013). *Design, Make, Play, Growing the Next Generation of STEM Innovators* (New York: Routledge).
- Miller, J. D. (2010). Adult Science Learning in the Internet Era. *Curator, Mus. J.* 53 (2), 191–208. doi:10.1111/j.2151-6952.2010.00019.x
- National Research Council (NRC) (2011). *Learning Science through Computer Games and Simulations*. Washington, DC: The National Academies Press.
- National Science Board (NSB) (2018). *Science and Engineering Indicators 2018. NSB-2018-1*. Alexandria, VA: National Science Foundation.
- Neville, M. (2010). Meaning Making Using New Media: Learning by Design Case Studies. *E-learning and Digital Media* 7 (3), 237–247. doi:10.2304/elea.2010.7.3.237
- NRC (2012a). *A Framework for K-12 Science Education, Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press.
- NRC (2012b). *Education for Life and Work, Developing Transferable Knowledge and Skills in the 21st Century*. Washington, DC: The National Academies Press.
- NRC (2015). *Identifying and Supporting Productive STEM Programs in Out-Of-School Settings*. Washington, DC: The National Academies Press.
- O'Connell, K. B., Keys, B., Storksdieck, M., and Rosin, M. (2020). Context Matters, Using Art-Based Science Experiences to Broaden Participation beyond the Choir. *Int. J. Sci. Educ. B* 10 (2), 166–185. doi:10.1080/21548455.2020.1727587
- Searle, K. A., Casort, T., Litts, B. K., Brayboy, B. M. J., Dance, S. L., and Kafai, Y. (2018). Cultural Repertoires, Indigenous Youth Creating with Place and story. *Int. Soc. Learn. Sci. Proc.*, 697–704. <https://repository.isls.org/bitstream/1/485/1/169.pdf> (Accessed March 31, 2021).
- Smith, G., and Sobel, D. (2010). *Place- and Community-Based Education in Schools*. New York, NY: Routledge.
- Sobel, D. (2005). *Place-based Education, Connecting Classrooms and Communities*. Great Barrington, MA: Orion Society.
- Storksdieck, M., Stylinski, C., and Bailey, D. (2016). *Typology for Public Engagement with Science, A Conceptual Framework for Public Engagement Involving Scientists*. Corvallis, OR: Center for Research on Lifelong STEM Learning.
- Vekiri, I. (2013). Information Science Instruction and Changes in Girls' and Boy's Expectancy and Value Beliefs: In Search of Gender-Equitable Pedagogical Practices. *Comput. Edu.* 64, 104–115. doi:10.1016/j.compedu.2013.01.011
- Vos, N., Van Der Meijden, H., and Denessen, E. (2011). Effects of Constructing versus Playing an Educational Game on Student Motivation and Deep Learning Strategy Use. *Comput. Edu.* 56 (1), 127–137. doi:10.1016/j.compedu.2010.08.013
- Wagler, M., and Mathews, J. (2012). In "Up River, Place, Ethnography, and Design in the St. Louis River Estuary," in *Mobile media Learning*. Editors S. Dijkers, J. Martin, and B. Coulter (Pittsburgh, PA: ETC Press), 41–60.

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Copyright © 2021 Davis, Kamarainen, Storksdieck, Gagnon, Kermish-Allen and Riedinger. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.