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Design Scaffolding for Computational Making in the Visual Programming Tool ARIS

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DESIGN SCAFFOLDING FOR COMPUTATIONAL MAKING IN THE VISUAL

PROGRAMMING TOOL ARIS

by

Whitney E. Lewis

A thesis submitted in partial fulfillment
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of

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ABSTRACT

Design Scaffolding for Computational Making in the Visual Programming Tool ARIS

by

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Utah State University, 2018

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Computational making is a process that combines programming with the creation of a physical or digital artifact. Integrating computation and making into one process is a complex task for learners to navigate; they must learn a computer language while also conceptualizing and implementing their ideas. To improve support for those navigating computational making tasks, researchers must explore and integrate 'design scaffolds' (i.e., intellectual supports) into computational making. Design scaffolds can help learners develop ideas and bridge gaps between envisioned ideas and their ability to program them.

In this thesis, I explored how design scaffolds help learners to progress through a computational making process with the visual programming platform Augmented Reality Interactive Storytelling (ARIS). Visual programming platforms are tools that allow non-programmers to learn programming concepts without knowing specific syntax of a programming language. ARIS is unique in its use of location-based functionality to help users build experiences and games like Pokémon Go.

To explore how design scaffolds could better support computational makers in

ARIS, we collected qualitative data from both ARIS designers and learners. Data for the ARIS designers consisted of five interviews. For the learners, we collected data from 11 learners (11 female, ages 11-16) during an ARIS workshop. Data included field notes, audio, photos, and videos alongside five interviews with six of the learners. Learners went through a computational making process that incorporated design scaffolds aimed to improve the progression from idea development to implementation via programming with ARIS. The design scaffolds included an example game, open discussion, debugging activity, and storyboarding tool.

All ten interviews and workshop field notes were analyzed by open-coding and triangulating the workshop audio recordings, photos, and videos to guide our understanding and interpretations. From this analysis process, we learned how the design scaffolds affected learners' computational making process and identified improvements for the design scaffolds.

(107 pages)

PUBLIC ABSTRACT

Design Scaffolding for Computational Making in the Visual Programming Tool ARIS

Whitney E. Lewis

In this thesis, I explore how design scaffolds, or (i.e., intellectual supports) can assist learners engaging with computational making processes. Computational making combines programming with artifact production. Due to the complexity of tasks involved in computational making, there is an increasing need to explore and develop support systems for learners engaging with computational making.

With $3,000 funding from Utah State University's College of Education and Human Services, an undergraduate researcher and I, who both have experience with youth and computational making research, explored how design scaffolds impact youth engaging with computational making processes. To do so, we held a workshop where 11 learners (11 female, ages 11-16) used ARIS, a platform designed for non-programmers to create mobile games. In addition, we interviewed five ARIS designers who were able to evaluate our design scaffolds.

We provide insights for improving the use of design scaffolds in computational making with ARIS specifically that also apply broadly to computational making processes. Moreover, we developed an ARIS course that teaches educators to use a design scaffold tool for ARIS. This research provides immediate benefits for educators who access the ARIS course and researchers seeking to improve upon design scaffold research for computational making processes.

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INTRODUCTION

Incorporating computational thinking into education has become a priority for researchers and educators since Wing (2006) argued that computational thinking is a "universally applicable attitude and skill set" for everyone to learn (p. 33). One approach to incorporating computational thinking into education has been to introduce these skills through a *computational making* process (Rode et al., 2015), or engaging in a making process to create a product while using computational thinking skills. Computational making activities include electronic textiles (e-textiles) and visual programming. In this thesis, I focus on visual programming activities.

Computational making is a unique design activity that is garnering more attention by educators and researchers because there is early evidence suggesting computational making with visual programming tools, digital interfaces that aid novices in programming and coding, develops computational thinking skills. (Brennan & Resnick, 2012; Litts, Lewis, & Mortensen, under review). The computational thinking skills developed and used in the computational making processes are requisites for programming and computer coding. Such skills include algorithmic thinking, decomposition, conditional logic, and debugging (Grover & Pea, 2013). The evidence found thus far around computational making supporting computational thinking skill development has prompted further research investigations and discussion around computational making in education. While computational making is not the only way to teach computational thinking skills and making practices, I have chosen to focus on it because of its promising outcomes.

Currently, researchers in computational thinking and making are investigating

whether and how computational making is successful at teaching computational thinking skills (Lye and Koh, 2014). Such research focuses on how the product (i.e. the game or e-textile that is developed) exhibits computational thinking skills versus the potentially complex process it takes to successfully participate in a computational making experience, which is comprised of not only computation, but also, a design process that includes brainstorming, researching, prototyping, and iterating. With the growing evidence that computational making with visual programming tools develops computational thinking skills, there is a need to shift the research from gauging how computational making promotes computational thinking to how these computational making activities can be better supported.

The Computer Science for All initiatives (The White House, 2016) have encouraged development of learning tools that promote computational thinking in education. With this broad call, one challenge that educators, researchers, and designers should begin to address is the lack of discussion and development of design scaffolds (i.e. activities, tools, and prompts that aid in the design process) for computational making processes. While scholars have implemented design scaffolds alongside their computational making activities, they have yet to study the effectiveness of the design scaffolds (i.e. Litts, Kafai, & Dieckmeyer, 2014; Lye and Koh, 2014). In this thesis, I examine the effectiveness of design scaffolds that support ideation (i.e., development of ideas) in computational making.

With his Logo Turtle, Papert (1980) demonstrated the need for tools used before the development or programming phase of computational making. Such tools can support youths' ideation by helping to solidify abstract ideas like computational thinking, which

is the goal of computational making. With the rise in computational making in education, there is an increasing need for design scaffolds that support learners prior to the programming phase of computational making activities (Lye & Koh, 2014).

In this thesis, I address how design scaffolds aid learners using visual programming tools during the ideation phase of the computational making process. I do so by implementing introduction activities and a storyboarding tool as design scaffolds for learners engaged in computational making processes with the visual programming tool Augmented Reality and Interactive Storytelling (ARIS; Holden, Gagnon, Litts, & Smith, 2014). ARIS is a free, open-source visual programming platform available via a web-based editor and an iOS app. I redesigned current design scaffolds used in ARIS's computational making process and used learners and ARIS designers to test the redesigned introduction activities and storyboarding tool. The redesigned scaffolds combine a specific sequence of supporting introduction activities that transition novice learners into the ARIS interface (Puntambekar & Kolodner, 2005). Furthermore, it utilizes a storyboarding tool to support learners' ideation. During my previous ARIS facilitations and research experiences, I observed challenges with existing ARIS design scaffolds. Thus, I used ARIS as a vehicle to better understand the role of design scaffolding in computational making processes while also working to build better scaffolding for ARIS specifically.

I conducted this exploration with two simultaneous studies of two different types of participants. The first study tested the redesigned scaffolds with youth learners who participated in an ARIS workshop. The redesigned scaffolds included introduction activities and a storyboarding tool. In the second study, I gathered evaluations and

feedback on the redesigned scaffolds from ARIS designers, which was incorporated into the introduction activities and storyboarding tool to better support learners' computational making in ARIS. By redesigning these two ideation scaffolds, testing them with youth learners, and evaluating them with ARIS designers, I examined how design scaffolds supported the computational making process in ARIS. This approach allowed me to address two research questions (RQ):

> Study One RQ (youth learners): How do introduction activities and storyboarding affect learners' computational making process in ARIS?
>
> Study Two RQ (ARIS designers): How do ARIS designers evaluate introduction activities and storyboarding as support for learners' engaging with computational making in ARIS?

Collectively, this work contributes insights to the fields of learning sciences, computer science, and design as they pertain to using design scaffolds to support the computational making process.

LITERATURE REVIEW

Constructionism

In this study, I take up a constructionist lens toward learning. Constructionists believe that knowledge is rooted in our experiences and that tangible artifacts created from this knowledge is a physical representation of learning (Kafai, 2006; Papert, 1991). For example, when a student creates a game via a visual programming tool, the game that was produced represents their computational knowledge. The experiences we have act as "active exploration" as learners compare what they know to their current knowledge and either add or adjust (Ke, 2014; Papert, 1980). Through this lens, as learners create computational making artifacts using visual programming tools, they are also creating representations of their computational thinking knowledge. In addition to tangible artifacts being representations of learning, these artifacts can also be used as "objects-to-think-with" (Papert, 1980, p. 11), or artifacts that can help learners as they interact with the digital world. Papert's (1980) LOGO turtle was an example of using a physical object-to-think-with while learners engaged with a digital environment. With the LOGO turtle, learners could see the output of their programming commands as the turtle moved in response. For example, when a learner would input a command for the turtle to turn left 90 degrees, they could see the turtle turn to the left 90 degrees. Like the LOGO turtle, the storyboards will act as "objects-to-think-with" as learners engage in the computational making process. With this lens, the storyboards become a tool learners use to develop their idea and think about how that idea will be realized in the visual programming tool throughout their making process. This lens is important because it justifies the use of storyboards as a tool that can be leveraged to prepare learners to make

in a digital space like ARIS as well as aid throughout their making process as an "object-to-think-with" (Papert, 1980).

Computational Making

Computational making- using computational thinking skills while engaging in a making process to create a product- has become a key means for researchers to explore computational thinking in education. Promising results demonstrate that learners engaging in computational making develop computational thinking skills (Brennan & Resnick, 2012; Litts, Lewis, & Mortensen, under review), which has led to further research and discussions about computational making in education. This research discusses both visual programming and e-textiles computational making activities (Litts, Kafai, Lui, Walker & Widman, 2017; Lye & Koh, 2014; Rode, et al., 2015). E-textile activities use conductive materials, such as conductive thread, so learners can sew circuits and electronics (e.g., LED lights) onto fabric.

Researchers in the computational making world are currently investigating how visual programming tools can expand computational thinking skills through game development. Lye and Koh (2014) reviewed 27 intervention studies to examine how computational thinking developed through programming and found that current studies are focused on "issues related to the computational thinking dimension of computational thinking concepts" (p. 54). The dimensions included concepts, practices, and perspectives, which respectively represent: introducing computational skills such as variables and loops, learning iterative problem solving, and developing identities in these contexts. Most of the 27 studies focused on how the computational making process facilitated learning of computational skills, iterative problem solving, and identity

development. They did not focus on how to better support the computational making process with design scaffolds. Additional and follow-up studies used intervention approaches to facilitate computational thinking. Such approaches included "constructing programs with scaffold" (Lye and Koh, 2014, p. 57) where learners were "not left alone to explore programming" (p. 57). Lye and Koh identified the following scaffolds in these studies: reflection, information processing, computer scaffolding, teachers' support, parents' support, peer support, and pair programming. Despite current research that included scaffolds in the design process, Lye and Koh (2014) still emphasized the need for more research on the scaffolding process. Scaffolds can better support the learner as they develop ideas that are subsequently reconciled within constraints of the visual programming tool.

Research has not only assessed how e-textile projects promote computational learning, but is moving towards evaluating processes needed for successful computational makers in e-textiles projects. Recently, researchers measured high school students' competency in designing a circuit, reading a code-able circuit, and then remixing the circuit, which used both circuit design and reading (Litts et al., 2017). While this research focused on how the process facilitates learning circuitry, Rode, et al. (2015) shifts focus to the process itself by identifying skills needed to have a successful computational making process. Researchers identified aesthetics, creativity, constructing, and visualizing multiple representations as important factors in the students' e-textile computational making process. These skills go "beyond those of computational thinking," and were deemed necessary for students' success (p. 241). Litts et al. (2017) demonstrates the computational and technological skills gained through making e-

textiles. Rode, et al.'s (2015) study represents a 'process focus' by exploring the skills needed for successfully engagement in computational making of e-textiles. Similar to Rode et al. (2015), I aim to focus on the process used in computational making supported by visual programming tools. A 'process focus' will provide results that speak towards how design scaffolds can better support computational making.

Design Scaffolding

Scaffolding stems from a socioconstructivist perspective (Vygotsky, 1978), where scaffolding is the support from a knowledgeable entity who is interacting with and guiding the learner. Vygotsky's (1978) Zone of Proximal Development (ZPD) further addresses the need for scaffolding by representing the gap between learners' capabilities alone versus accomplishments with the help of more knowledgeable peers. Successful scaffolding supports learners crossing the "gap between the actual and potential" (Puntambekar & Kolodner, 2005). Researching design scaffolds can provide the needed support for learners to take on the complex design and computational task of computational making.

Learners participating in computational making activities are engaging with both computation and design processes as they develop ideas and make decisions on implementing their ideas given the constraints of visual programming tools. I will outline design scaffold research for both design and computation activities in order to cover both aspects of computational making.

Scaffolds in Design Activities

Research on scaffolds for design activities emerged through Learning by Design, inquiry-based, and problem-based learning strategies. Researchers have begun exploring

support for the complex and iterative design process required by these learning strategies. For example, Hsu, Lai, and Hsu (2014) used a design model for distributed scaffolding (DMDS) that included features such as teacher facilitation and curricular scaffolds to help students learn about plate tectonics while also going through a "recursive process of designing-implementing-refining." Each scaffold activity aimed to help "navigate inquiry," "structure tasks," "support communication," or "foster reflection." Their findings indicated that using different types of written and teacher support scaffolds for the same activity was most successful. Their results demonstrate the need for scaffolds and the importance of multiple types of scaffolding, which is echoed in subsequent research (Puntambekar & Kolodner, 2005). Puntambekar & Kolodner (2005) demonstrate that design scaffolds are not just a single tool, but rather, a system of tools, prompts, and collaborations. The authors explored how a design diary helped support students' design activities and followed up with a second study with added prompts and collaborative interactions in hopes of increasing the engagement. From their two studies, they found: 1) design scaffolds must use multiple "tools and agents" and 2) the sequence of supporting activities (i.e., design scaffolds) matters. Both studies illustrate how the tool, as well as the prompts and activities that surround the tool are both important for supporting learners' design process. In the computational making process, it is vital to consider both the support activities (i.e., agents) and support tool to ensure the learner is successful. In addition to research surrounding design activity scaffolds, research has begun to address specific design activity scaffolding tools, which informed the inquiries found in this thesis.

The specific design scaffold I explored is a storyboarding tool, which is a design tool used by professional film writers and game designers to develop ideas prior to developing their film or game. The storyboard acts as a 'minimal viable product' (Lenarduzzi & Taibi, 2016), or a low-cost, low-resource artifact, that can help the designer visualize their story. By storyboarding the idea, the designer can begin to refine and adjust their idea before implementing it (IDEO.org, 2015). In game design, storyboards are a way for the designer to outline the game world, but due to storyboards' linear nature, game designers are encouraged to include branches that represent the interactivity in the game (Adams, 2014). Adams describes this as a "flowboard", which is made up of index cards with drawings connected by arrows, and most importantly, the actions available to players. Because learners make games in the computational making process, it follows that using storyboards as a scaffold would be useful to learners. Using a storyboard as a flowboard aligns with the design needs of learners who might be creating games with multiple paths the player can take. However, learners not only need an outlet for developing ideas, but also a way to develop ideas within the constraints of the computational or visual programming tool used. Including a way for learners to develop ideas within the constraint of the tool will begin exposing learners to vocabulary and features that supports their computational making process.

Computational Making Scaffolds

Beyond design activities and video game development, research on scaffolds for computational making activities has identified seven general scaffolding techniques found within 27 studies in computational making literature (Lye and Koh, 2014). Four of the seven scaffolding techniques heavily relied on collaboration support from either a

teacher, parent, or peer. Two of the supports- reflection and information processing-

hinted at the importance of activities that support learners during the computational

making process. Although none of these 27 studies emphasized or made use of tools,

Litts, Kafai, and Dieckmeyer (2014) illustrates how non-digital tools in the computational

making process can support learners' ideation. In this study, high school students

designed the functions and layout of a circuit using a blueprint, prior to the actual

creation. Students' feedback noted that the design documentation helped "communicate"

their ideas because they were able to refer back to the design document throughout the

circuit making process. Because the blueprint acted as an "object-to-think-with" as

learners engaged with the computational making process, we hypothesized a storyboard

tool should also support learners engaging with computational making when using a

visual programming tool.

Design scaffold and computational making literature were both critical for our

study. They provided evidence that scaffolds are necessary in computational making

processes and informed how we redesigned the introduction activities and storyboarding

tool. The literature illustrates the need to use non-digital tools (e.g., storyboards and

blueprints) prior to engaging with a visual programming tool.

ARIS

I used a free, open-source, and online visual programming tool, ARIS, which is

where non-programmers can create location-based and mobile games. Learners program

games using a web-based editor, accessible at www.arisgames.org/editor. They can then

playtest their game or other ARIS games using an iOS app, free to download from the

Apple App Store. I previously participated in research that explored the ARIS tool,

which is discussed below, providing me with first-hand experience and knowledge of the tool.

In this section, I describe the ARIS platform in detail, followed by a discussion of previous research done with ARIS. Some research argues that ARIS supports development of computational thinking skills when making games in ARIS (Litts, Lewis, & Mortensen, under review). Another body of research details the variety of design scaffolds used to support the making process in ARIS (Litts, Martin, & Gagnon, 2013), which I redesigned for these studies in light of recently observed challenges during the transition from storyboard to building in the ARIS editor. This section concludes with an outline of my previous experience with ARIS and how it informed this inquiry.

About the ARIS Platform

In educational settings, ARIS has supported learners creating mobile games in disciplines such as civic literacy and history (Dikkers, Martin, & Coulter, 2011; Holden, Dikkers, Martin, & Litts, 2015). ARIS uses a web-based editor and a client-based app for iOS devices, where learners respectively program and playtest games. In contrast to block-based programming strategies used in visual programming tools such as Scratch (Resnick et al., 2009), ARIS leverages a narrative approach. The narrative approach programs using game objects such as scenes, conversations, and characters that ARIS games are built upon. In addition, learners create a narrative by incorporating their own text and media content. A complete list of ARIS game objects includes: scenes, locks, events, conversations, plaques, items, quests, and factories. Learners use these game objects to create unique ARIS games. For example, learners often use scenes to organize their games into different levels (Figure 1). Next, learners use locks, a game object the

represents ARIS's logic, to control the flow of the game by determining when ARIS game objects appear (Figure 1) to the player. For example, the green arrow in Figure 1 represents a lock in the ARIS editor that forces the player to exit the conversation 'Nice job' (Figure 1) before continuing to the 'Gold Bananas' scene.
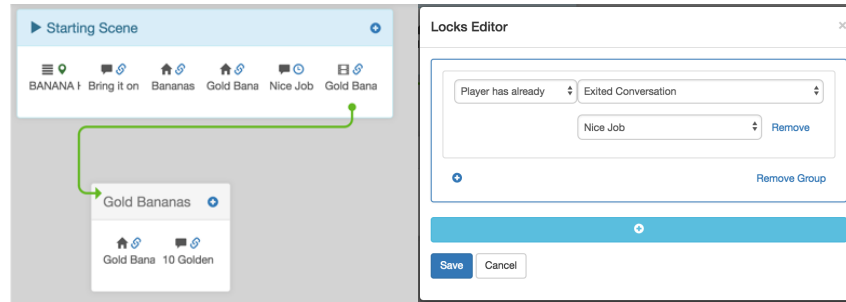
Figure 1. Scenes with a green arrow depicting a lock (left), and the lock editor (right) in the ARIS.

Events, a game object that affects a player's inventory, are used to give or remove an item after a player completes a task. Conversations use a decision tree, or branching logic, to create interactions between the player and non-playable characters (NPCs) in the game (Figure 2). Learners can use conversations in multiple ways to give players choices with different results as the game progresses. For example, learners have used conversations to simulate battle actions for a player to choose from, each with different results.
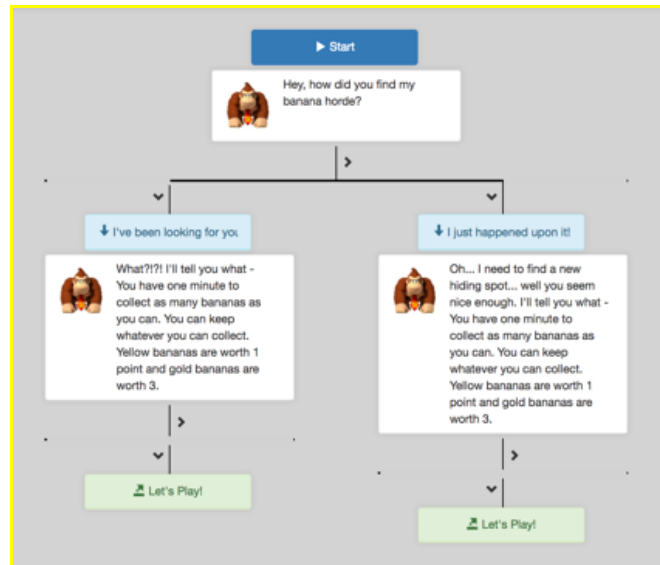
Figure 2. Example of branching logic structure used to build conversations.

Learners can use plaques, a game object that displays content such as text or media, in many ways. For example, a plaque can show players a captioned picture or video that provides needed information for the game. Items are digital objects the player can collect and add to their inventory. Learners use quests to direct players on tasks they need to complete and when a task is completed. Quests consist of two locks: one that determines when the player receives the quest, and a second that determines when the quest is complete. The first lock is released when the player receives a quest to find an item, such as a gem. Once the player picks up the gem, the quest would be completed, thereby releasing the second lock. Lastly, factories spawn items at specific rates and distances from the player chosen by the learner (Figure 3). Factories act a lot like how Pokémon Go spawns Pokémon around locations.

Several of the ARIS game objects correspond with specific computational thinking skills. For example, scenes and locks represent logic, while factories correspond

with data representation. I discuss these connections further in the following section.

Figure 3. Factories, as seen in the ARIS editor.

ARIS as Computational Making

Learners engage in computational making and computational thinking skills in ARIS by building a game or experience guided by their interests and ideas. In a recent ARIS workshop where youth created games like Pokémon Go using local animals, we explored how youth exhibited computational thinking skills (Litts, Lewis, & Mortensen, under review; Mortensen, Litts, Lewis & Benson, 2018). For one youth, computational thinking concepts (e.g., sequences, data, operators, and conditionals) (Brennan & Resnick, 2012) were connected with specific ARIS game objects (e.g., scenes, items, factories, and locks, respectively). More broadly, participants in this workshop also displayed these same computational thinking concepts as they created their game in

ARIS. We found that learners engage with computational making as they build games in ARIS. This research supports ARIS as a visual programming tool that helps learners engage with computational making. Thus, there is a need to explore the design scaffolds used for ARIS's computational making process.

Current Design Scaffolds in the ARIS Making Process

When running an ARIS workshop, facilitators typically guide learners through a specific computational making process (Figure 4) that includes an introduction to ARIS, research on the topic, storyboarding to create the narrative, and then development in ARIS (Litts, Martin, & Gagnon, 2013). My two studies focused on redesigning the introduction activities and storyboarding tool- two existing scaffolds that support learners' computational making in ARIS.

Figure 4. The ARIS design process with the parts I redesigned outlined in green.

Currently, introduction activities include showing learners examples of ARIS games or having learners play an ARIS game. Subsequently, there is a facilitated discussion showing learners the game objects used to create ARIS games. Next, the storyboarding tool uses ARIS-specific storyboarding cards (Figure 5) to help familiarize the learner with ARIS. The learner can fill in the cards with their ideas and tape the cards onto the storyboard paper to begin to think about how their idea will be programmed in ARIS.

Figure 5. Four typical storyboarding cards used in the ARIS design process. These cards do not reflect our redesigned storyboarding tool.

The learner can use these cards to develop their game while storyboarding and think about how to construct their game using the ARIS game objects (Figure 6).

Figure 6. A learner using the ARIS storyboarding cards to design their idea.

ARIS game objects with corresponding storyboarding cards include characters, plaques, conversations, items, quests, and factories. The goals of the ARIS cards are: "1) to offer a concrete outlet for ideas; 2) to situate ideas within the constraints of the tool; and 3) to immerse learners within the vocabulary of the tool" (Litts, Martin, & Gagnon, 2013). Findings from pilot studies suggest that storyboarding cards are effective tools for helping undergraduate students develop their ideas within ARIS (Litts, Martin, &

Gagnon, 2013; Gagnon, Vang, & Litts, 2015). However, recent workshops observed

challenges as youth learners transitioned from the current storyboarding process into

ARIS. To address these challenges, I changed the introduction activities and

storyboarding tool in order to explore how design scaffolds affect learners' computational

making in ARIS.

My Participation in Prior ARIS Research

Three of four pilot workshops preceding this study used a twelve hour ARIS

design process (Figure 4) with youths. In the fourth workshop, we tested how a new

introduction activity- debugging- could help familiarize learners with ARIS prior to

developing their game ideas (Lamarra, Litts, Lewis, & Mortensen, 2018). Data from

these workshops informed this thesis research, but we did not use it in this study.

Two of the three twelve hour workshops had participants use ARIS to learn about

their local environment while making a game like Pokémon Go using local plants and

animals. Several participants created ecological stories with food chains and required

players to go outside to catch and evolve digital animals (Litts, Lewis, & Mortensen,

under review). In the third twelve hour workshop, Native American youth used ARIS to

make mobile experiences that related to their culture and stories. One group created a

narrative where players had to learn about cultural representations in order to escape a

local baseball stadium. In all three of these workshops, the participants followed the

ARIS design process, which included an introduction to ARIS, research on the topic,

storyboarding the game idea, and lastly, developing that idea on the ARIS editor. We

observed that the storyboarding cards were helpful in planning the project (Figure 5), but

were ineffective for reconciling learners' design visions. Cards were unable to help

learners conceptualize how they would program their ideas within ARIS. This created difficulties when participants began building within ARIS.

The fourth workshop pilot tested a debugging activity to inform how I would redesign the introduction activities (Lamarra, Litts, Lewis, & Mortensen, 2018). Learners in this fourth workshop did not go through a full design process, and thus, did not do research on a topic or use the storyboarding tool. Instead, they played an example game, participated in a debugging activity, remixed the example game, and created their own game. Because the debugging activity had promising results for helping learners understand ARIS, we incorporated the activity into the ARIS design process for this thesis. This allowed us to explore how the debugging activity affected first-time learners' trying to create a game through an ARIS design process with the storyboarding tool.

These workshops primarily focused on the affordances and constraints of the ARIS editor, which revealed how to improve introduction activities and storyboarding tools to better support learners' transition from developing their ideas to programming in the ARIS editor. These observations prompted me to redesign the introduction activities and storyboarding tool to better support learners' computational making processes in ARIS.

RESEARCH APPROACH

I used a design based research approach (DBR) to conduct this study. DBR is an educational research approach that bridges research with real problems faced in practice. This is done by connecting research interventions with theory (The Design Based Research Collective, 2003). DBR is made up of five characteristics: 1) the research has goals of both designing learning environments and theories, 2) the development of interventions along with the research is an iterative process with "design, enactment, analysis, and redesign," 3) the design research must lead to theories that "communicate relevant implications" for other researchers and practitioners, 4) the research must be done in the "authentic" setting to account for learning issues in context, and 5) there must be methods that can document and "connect the process of enactment to outcomes of interest" (The Design Based Research Collective, 2003). I will address each DBR characteristic and explain how it is being represented and/or enacted in my own research.

First, this study aimed to develop learning environments and theory by asking questions that included both the effect of the introduction activities and storyboarding tool scaffolds as well as how these scaffolds could be modified. The first study's research question aimed to contribute broader implications concerning design scaffolds for computational making while the second study's research question was inspired by a desire to improve the introduction activities and storyboarding tool for a more successful learning environment in ARIS. In addition to my research questions being led by these goals, I have also added to the ARIS learning environment by creating a video course on how to use the storyboarding tool. This course is free to access and is housed on the ARIS courses webpage (https://fielddaylab.wisc.edu/courses/).

Second, my redesign of the introduction activities and storyboarding tool are part of a larger design research endeavor that has already taken the storyboarding tool through previous design iterations and has added implications for using a tool like this to the literature (Litts, Martin, & Gagnon, 2013; Gagnon, Vang, & Litts, 2015). I added to this research by incorporating introduction activities as well as continuing the exploration of the storyboarding tool and taking these scaffolds through another redesign, enactment, and analysis cycle. I will also begin the next redesign cycle by identifying and making changes to the introduction activities and storyboarding tool, which are informed by both studies.

Third, through my first study's research question, I contribute knowledge to broader conversations around how design scaffolds can be leveraged in computational making processes. This will lead to implications for other computational making activities (refer to DISCUSSION section), which is relevant due to the current discussions around computational making in education, how it can support computational thinking skills, and the explicit call from Lye & Koh (2014) to research design scaffolds for computational making processes.

Fourth, this study takes place in a typical out-of-school learning environment (a makerspace afterschool workshop) to account for "learning issues in context." By conducting this study in this type of environment, our findings were able to better represent real difficulties learners and facilitators face when trying to scaffold computational making processes. Future iterations of this research can use these findings to inform research done in an in-school learning environment, where the setting will account for additional learning challenges in a classroom context.

To address the final DBR characteristic, I strived to use methods throughout my research process, which are described in detail below, that included multiple types of data, an additional researcher for reliability checks, and a systematic approach to data collection and analysis. By doing this and then clearly articulating what I did in this thesis, I aimed to connect the research methods I used with the resulting findings.

By using a DBR approach, I have stood true to core beliefs that research should contribute usable knowledge while also contributing usable products. This approach also supported the iterative process it can take when developing design scaffolds. Lastly, this approach steered my effort to follow systematic methods that would take me from my research questions to my findings.

CONTEXT OF STUDIES

I will introduce the context of both my studies by presenting the timeline for each and how they overlapped. Following this, I will explain the redesign of the introduction activities and storyboarding tool. This redesign was done prior to data collection, and the resulting introduction activities and storyboarding tool were used during data collection in both studies. Lastly, I will discuss issues of trustworthiness including strategies I used to increase the trustworthiness of both studies.

Study One and Study Two Timeline

In Study One, I held an ARIS workshop with youth learners where I investigated the effectiveness of the introduction activities and storyboarding tool. In Study Two, I interviewed ARIS designers, and they evaluated the introduction activities and storyboarding tool. In order to complete the research project within the time allotted, I began the ARIS workshop with the learners before I interviewed the ARIS experts (Figure 7). Ideally, I would have been able to first interview the ARIS designers and implement additional changes based off their evaluation before holding the ARIS workshop with youth learners. This timeline limited my ability to test the effectiveness of changes made to the introduction activities and storyboarding tool that came as a result of the ARIS designer feedback with youth learners, but I was still able to identify changes that were informed by both Study One and Study Two, which can be used in future research iterations.

First day of ARIS workshop

Interviewed ARIS designers

Second day of ARIS workshop

Interviewed youth learners on last day of ARIS workshop
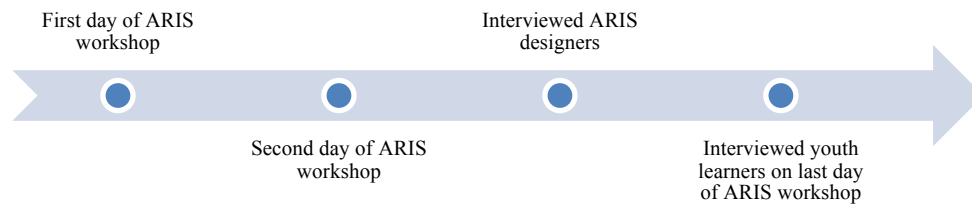
Figure 7. Timeline of Study One and Study Two.

Redesigned Introduction Activities and Storyboarding Tool

Factors Informing the Updated Design

I now discuss the changes made to the introduction activities and storyboarding tool prior to our data collection. Changes were informed by design scaffold literature alongside multiple antecedent activities, including: (1) user tests conducted for a class assignment, (2) three workshops using the old ARIS design process and storyboarding tool, and (3) a pilot workshop evaluating a debugging activity.

First, I used a classroom assignment to conduct three user tests focused on introduction activities and the ARIS storyboarding tool. This class assignment was not covered by IRB, so I will only describe the user tests and how they informed my redesign. Each 1.5-hour test contained adult learners that went through the following introduction activities and storyboarding process prior to building their game in the ARIS editor:

1. Played an example ARIS game

2. Discussed different ARIS game objects with a facilitator

3. Storyboarded their favorite game or story to remix in ARIS

The example game (1) and ARIS discussion introduction activities (2), above, were

informed by previous ARIS workshops, where we introduced learners into ARIS by playing an example game followed by a discussion. The storyboarding tool (3) was informed by the ARIS design process, which historically used a storyboarding tool.

Through these user tests, I learned that the ARIS storyboarding cards can overwhelm learners when only paired with two introduction activities (i.e., example game and ARIS discussion). Thus, I employed a debugging activity within the introduction activities after the ARIS discussion. While the storyboarding cards could be overwhelming, I noticed that learners had difficulty knowing how to build their game in the absence of these cards. These learnings indicated that my redesign should consider the importance of 1) including introduction activities that expose learners to ARIS game objects prior to storyboarding their game idea and 2) incorporating ARIS game objects during the storyboarding phase.

In addition to the user tests, three previous workshops that used the ARIS design process informed changes to the storyboarding tool. These changes were to simplify the storyboarding cards and add a card that represented locks (i.e., the logic component of ARIS). I simplified the storyboard cards by removing unnecessary game object information for the idea development phase of the computational making process. For example, a previous 'item' storyboard card included optional item feature information such as weight, max quantity, and whether the item could be dropped and/or destroyed (Figure 8). The redesigned item card removed all this information and added a short definition of items (Figure 8).

Figure 8. The previous item storyboard card (left), and the redesigned item

storyboard card (right).

In these workshops, participants had many questions about 'locks' in ARIS, so I

added a storyboard card for locks in hopes of exposing learners to the sequence logic

behind a game in ARIS (Figure 9). I incorporated this card into the learners' ARIS

storyboarding card stack as part of the storyboarding tool.
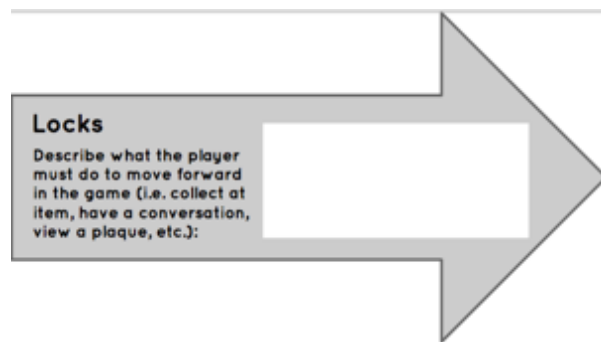
Figure 9. A new ARIS storyboarding card that represents ARIS's locks functionality.

The final precedent workshop piloted a debugging activity directly informed how

I could redesign introduction activities to better prepare learners for computational

making in ARIS. For the piloted debugging activity, learners worked in pairs to find and

fix pre-set bugs/problems with the locks in an example game. This activity exposed learners to ARIS game objects, and specifically, the lock object that has been historically difficult for past ARIS learners. The debugging activity appeared promising in its ability to help learners better understand the ARIS game. Hence, I included the debugging activity was in the introduction activities for this thesis research.

I also used design scaffold literature to inform the redesign of the introduction activities and storyboard tool. Because scaffolding goes beyond the tool to include the agents (facilitation from teachers and peers and resources) and sequencing of activities (Puntambekar and Kolodner, 2005), I made sure to focus on introduction activities that accompanied the storyboarding tool. Previous research on both design scaffolding and storyboards supported the decision to use a storyboarding tool and provided insights on how that tool should support learners.

The Redesigned Introduction Activities and Storyboarding Tool

I used the redesigned introduction activities and storyboarding tool in both research questions to explore how design scaffolding affected learners' computational making in ARIS. The redesigned introduction activities examined in these studies included:

1. An example game that aligned with the workshop's prompt
2. An interactive discussion of the ARIS game objects used to create the example game
3. A debugging activity where participants worked in pairs to fix problems with a 'bugged' example game

The redesigned storyboarding tool used the following materials: black markers, colored

markers, large-format paper, tape, and ARIS storyboarding cards (Figure 10).

Figure 10. The redesigned ARIS storyboarding cards (not including item and locks, which are depicted in Figures 8 and 9).

Issues of Trustworthiness

Because I am conducting a qualitative study, I am concerned with issues of trustworthiness (Lincoln & Guba, 1985) not validity. Trustworthiness addresses issues of rigor by working to establish credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985). It is the job of the researcher to show how the study addresses each one of these categories. In addition, it is the job of the reader to judge the research based off the goals of the study and the area of research. For example, in my inquiry it is my job to show the reader the "truth" of these findings (credibility), the applicability of the findings (transferability), that the study was systematic and could be repeated (dependability), and that this study does not include concerning researcher biases (confirmability). It is then the job of the reader to judge this research through the research questions I have presented and within the context of education research. I will discuss additional strategies specifically used to increase the trustworthiness of this study, which included triangulation, consensus coding, and in situ member checks with learners.

Triangulation is when multiple types of data sources, methods, and researchers are used to "provide corroborating evidence" (Creswell, 2007). In my first study, I collected several different types of learner data, which I reviewed while writing field notes after each workshop day. By reviewing the learner data collected against itself, I could see the themes that were emerging in data analysis aligned with all the collected learner data. In addition to being able to triangulate the learner data against itself, I was also able to triangulate the learner data against the ARIS designer interview data from the second study to make sure the emerging ideas and themes aligned across participant types. For example, during the workshop, I had several instances in my field notes of learners who were having difficulty with the ARIS object locks. Learners then expressed that they had difficulty with locks in interview data. I was also able to triangulate this idea with ARIS designer interviews, where they described locks as being difficult for learners.

For this thesis work, I was able to collaborate with an undergraduate researcher who also had experience with youth and ARIS research. It was important to me that I included him throughout both studies because it added another researcher's eyes and mind to the data, which would help avoid biases and allowed me to double check the "truth" of what I was seeing emerge with this researcher through "debriefings" (Creswell, 2007). In addition to this continuous informal check between the undergraduate researcher and I, we also did a more formal check of our analysis process through consensus coding (Saldana, 2009). Consensus coding is when multiple researchers code the data for the purpose of analysis and then participate in "intense" discussion of their codes in order to come to agreement on what content received what codes. We

participated in consensus coding for both studies. This process and the results are discussed below in each study's data analysis section.

Lastly, I attempted to employ some type of member check with the learners in the first study by informing the semi-structured interviews with data collected throughout the workshop. For example, one youth learner started storyboarding by writing down their game idea. Then, on the second day of storyboarding, she began adding numbers, or a sequence to those ideas. I was able to explicitly ask about this transition in the interview:

> "Um, so from your first day storyboarding, you kind of had, like, a lot of ideas, and then your second day, I noticed you wrote down numbers. So, can you tell me about kind of what happened in between kind of having those thoughts to getting to those kind of, like, numbers?" (Interview, February 5, 2018)

An official member check is described as "soliciting participants' views of the...findings and interpretations" by taking data and rough drafts back to the participants (Creswell, 2007). While I did not take analyzed data or rough drafts back to the learners or ARIS designers because of the short time frame of my study, I did try to employ some participant interpretation of data. By doing this, the learner was able to do some interpretation of their own actions, which helps limit my interpretations and biases on the data.

STUDY ONE: LEARNERS' DESIGN SCAFFOLDING EXPERIENCE

With Study One's research question, I investigated two design scaffold strategies: 1) introduction activities and 2) a storyboarding tool. Specifically, I explored the effectiveness of these redesigned scaffolds when on ramping learners to ARIS and helping learners with ideation in the ARIS computational making process. In the next section, I will explain the participants used for this study, the ARIS workshop the youth learners participated in, and the data collection and analysis process. Following this, I will discuss the resulting findings for this study.

Participants, Data Collection, and Data Analysis

Learners are anyone who are engaging with the computational making process through ARIS and are unfamiliar with its functionality and features. This could include youth learners and adult learners such as educators. For this study, I focused on youth learners because they are the learners in typical education settings who are expected to go through computational making processes with the goal of learning computational thinking skills and design.

Participants and the ARIS workshop

Eleven youth learners attended the ARIS workshop (11 female, ages 11-16) and agreed to be a part of this IRB approved research study through both consent and assent. All the learners were female to fulfill the needs of separate study but was not a choice made for this thesis research. Of the eleven youth learners, nine fully participated in the study. One participant attended the first day before dropping out of the workshop due to time constraints, and one was only present for two out of the three workshop days. Three participants had participated in a previous workshop, so they had prior experience with

the ARIS platform. The previous workshop they attended was the previously discussed workshop (refer to ARIS section) where we piloted the debugging activity. This previous workshop included an example game, ARIS discussion, and debugging activity, but they did not engage with the storyboarding tool. This does pose a limitation because it is harder to make claims about how the introduction activities and storyboarding tool onboard novice learners into ARIS. Although, we can still see how these introduction activities and storyboarding tool help scaffold learners into computational making with ARIS more generally.

Four student researchers helped facilitate and collect data during this workshop. I acted as the lead facilitator with support from an undergraduate researcher who has also helped facilitate three previous ARIS workshops. Two doctoral researchers assisted with data collection including field notes, pictures, and videos during the workshop. We ran this workshop through a local makerspace club, which helped us to advertise and attract attendees. Participants of the workshop attended once a week for three weeks for two hours each meeting time.

During the ARIS workshop, participants went through an ARIS design process using the redesigned ARIS introduction activities and storyboarding tool. They had a total of six hours to go through this computational making process, which is half the workshop time we had in previous workshops. The time was cut in half so we could begin to work towards a quicker ARIS implementation process. On the first day, the learners played the example game, participated in an ARIS discussion, fixed a 'bugged' version of the example game (the debugging activity), were told the prompt they would use for their own games, and began storyboarding their idea. Because the focus was on

the effectiveness of the scaffolds we were using and not necessarily the content of the

game, we decided to do a prompt around citizenship in their community. This prompt

merely acted as a way to constrain ideas around a topic. Participants were not forced to

follow the prompt if ideas grew outside of citizenship in their community. The second

day was split into storyboarding and building in the ARIS editor. On the last day,

participants spent the entire time working on their game. Six participants also participated

in interviews on this day.

Data Collection

We collected qualitative data that included interviews (Appendix A), field notes,

audio, pictures, and video (Table 1). Of the eleven learners who participated in the

workshop, six were interviewed (Table 2) after going through the introduction activities,

storyboarding process, and building a game in the ARIS editor. These six were selected

because they represented a range of expertise with ARIS, a variety of experiences with

the introduction activities, and different types of engagement with the storyboarding tool.

For example, Samantha caught onto ARIS very quickly, while Sally did not understand

ARIS immediately. Another example of this is Lucy who enjoyed using the

storyboarding tool while Sarah did not like storyboarding. Lucy was also one of the three

participants who had previous experience in ARIS, so she was chosen to represent this

view. In addition, each of these six participants were present during the entire workshop.

Two of the six participants who were interviewed did a joint interview because they were

siblings and had worked on their storyboard and game jointly throughout the entire

workshop, so there was a total of five interviews with a total of six participants. I only

interviewed six participants because of time constraints for analyzing the data, and the six

who were selected represented the breadth of process and expertise in the workshop as described above.

The interviews for these participants were conducted by me, who did three interviews, and the undergraduate researcher, who did two interviews. Both of us conducted interviews because we were both going to be involved in the data analysis phase. While only six participants were interviewed, each of the eleven participants were represented in field notes, audio, pictures, and videos from the three days. Field notes were mainly done by the undergraduate researcher and I. There was one set of field notes completed by a doctoral researcher. The undergraduate researcher and I both had audio recorders each day of the workshop, which we took with us as we interacted with participants. Pictures and videos were mainly taken by a doctoral researcher and the undergraduate researcher. Pictures included photos of the participants during the workshop and documentation of their design process including photos of their storyboard after the first and second day of the workshop and screenshots of their ARIS game after the second and third day of the ARIS workshop. All data was uploaded and saved on Box.com to comply with security and confidentiality regulations.

Interviews	Audio	Field Notes	Photos	Videos
5 interviews	14 hrs. 10 min.	13 pages	141	1 hr. 21 min.

Table 1. Amount of each type of learner data collected.

Interviewed Participant's Pseudonym	Participant's Age
Sally	11

Tina	13
Stephanie	16
Lucy (has previous ARIS experience)	12
Samantha	12
Sarah	10

Table 2. Pseudonym and age of learner participants who were interviewed.

Data Analysis

The undergraduate researcher and I analyzed the learner data. These data included interviews, field notes, audio, pictures, and video from the ARIS workshop. All the interviews and field notes were coded while the audio, photos, and video data from the workshop were heavily referenced in field notes and were used during data analysis to triangulate themes. Between the undergraduate researcher and I, we listened to each audio recording and viewed and described each photo and video.

Coding process. We open coded the data with a with a qualitative software called Dedoose. We built a codebook, which would help distinguish what aspects of the introduction activities and storyboarding tool affected the learners' computational making process. I open coded all five learner interviews, and the undergraduate researcher open coded three learner interviews due to time constraints. In our first round of coding, we used descriptive and in vivo codes (Saldana, 2009), so we could form initial categories while still staying true to what participants actually said. After this first round of coding, I began to create categories, or pattern codes (Saldana, 2009), that would be used in the second round of coding. Before beginning the second round of coding, the undergraduate researcher and I met to make sure each of our codes were represented in these pattern

codes and created definitions for each of the codes to form our codebook for the learner

data. A summative version of this codebook can be referenced in Table 3.

     With this codebook, we began our second round of coding. First, we coded the

same three interviews that the undergraduate researcher coded in the first round of

coding. We each coded these three interviews, so we could participate in consensus

coding (Saldana, 2009) to ensure I was accurately applying the codebook across all five

interviews. After we had each coded the same three interviews, we went through the

consensus process where we compared the content we coded, and the codes we applied to

the content. This was a thoughtful process, where I, as the lead researcher, was mindful

about my position in the research and made sure to listen to and draw out the opinions

and thoughts of the undergraduate researcher. We discussed each discrepancy, and

through this discussion were able to achieve consensus on the codes that were applied to

the three interviews. I continued the second round of coding by coding the final two

learner interviews and the field notes. The goal of this coding process was to help identify

themes related to my inquiry by exposing me to the data multiple times while letting

those themes and ideas emerge.

Learner Codes	Code Definitions
Storyboard resistance	Participant speaks towards not finding use in storyboarding
Reconciliation support	Participant describes that storyboarding helps them figure out how they will make their game on the computer by either thinking about it beforehand or referencing their storyboard while making
Ideation support	Storyboard tool helps participant build their game idea

Storyboarding challenges	Difficulties participants had with storyboarding or with the storyboarding tool
Storyboard successes	Things the storyboard did well that don't fall under reconciliation or ideation
Storyboard process	Participant describes their method for storyboarding or how they went about storyboarding
Example game - challenge	Participant discusses difficulties or confusion with the example game
Example game - success	Participant describes positive feelings or affects related to the example game
Debugging activity - challenge	Participant discusses difficulties or confusion with the debugging activity
Debugging activity - success	Participant describes positive feelings or affects related to the debugging activity
ARIS language	Using the game objects to describe their idea or what they are having a hard time with - shows their understanding of the game object
Idea changed	Participant's game idea changed while storyboarding or while developing in ARIS
Help	When the participant asks for help from a facilitator or peer
Game description	Participant describes what their game idea is

Table 3. Summative codebook used for coding the youth learner data.

Findings

The findings for Study One focus on the six learners (five interviews) who were interviewed while drawing on field note, audio, photo, and video data that included all 11 learners when necessary. Pseudonyms are used for all learners. The redesigned ARIS introduction activities consisted of playing an example game, a discussion reviewing the ARIS game objects that were used to make the example game in the ARIS editor, and a debugging activity where participants fixed a version of the example game that was not working. Learners then used the redesigned storyboarding tool to storyboard their game

idea. Using various learner data, I will illustrate each introduction activity, the learners'

uses of the storyboarding tool, and the effect these scaffolds had on the learners'

computational making processes. In addition, I will discuss implications for changes.

Example game

The goal of the example game was to introduce learners to what an ARIS game

looks like and to facilitate discussion about ARIS game objects after the game was

played. The example game for this workshop first taught the learners about littering in

Cache Valley. Next, the learner collected digital litter and disposed of it at a virtual trash

can. After collecting digital litter, the game prompted the learner to collect real litter. The

game did not progress for two minutes, which is time the learner was supposed to spend

looking for and disposing of real litter. Lastly, the learner could then return to the

workshop room to find an image of a recycle sign. By using the camera on their iPad, the

image would direct the learner to a video about recycling trash. The game used location,

so the player needed to walk around to complete activities like collecting digital trash. On

the day of the workshop, the weather was cold and none of the participants wanted to go

outside to play the game, so instead, we played the game inside (Figure 11).

Figure 11. Participants playing example game.

There are two major findings concerning how the example game affected the learners' computational making process: 1) the location-based-ness of an example game, or lack thereof, can affect the learners' understanding of ARIS and 2) features of the example game were seen in the learners' final games. I will discuss each below followed by implications for these findings.

Learners' Understanding of ARIS. The weather was the main challenge with the example game because it limited our ability to highlight the location-based functionalities of ARIS. One participant, Samantha, explained that not going outside affected the example game activity for her. She said, "It was—they [the game] wanted us to, like, walk around and stuff and collect the items, which is—seemed like the whole point of the game, but we had to stay inside the room, so that didn't really make sense, I think" (Interview, February 5, 2018). It was also noted in field notes from both facilitators, the undergraduate researcher and I, that this activity fell short because we did not go outside. Tina was also unsure about what ARIS was during the example game activity. She described her experience before getting on ARIS as, "And, like, you know, you talked about it, but we weren't really sure what it [ARIS] was—or at least I wasn't until we got on." (Interview, February 5, 2018). It wasn't until Tina got onto ARIS as part of the debugging activity that she began to understand ARIS. Using a location-based technology has trade-offs of being able to engage learners with the outside world but at the cost of having to work around weather constraints, which has been noted in past ARIS implementations (Holden, Dikkers, Martin, & Litts, 2015). Samantha's explicit confusion over staying inside to play a location-based game supports the need to better plan for these constraints so learners can fully grasp what ARIS is, and the unique

location-based functionality it provides. If we were able to successfully do this in this workshop, Tina and others might have better understood what ARIS was before we began the debugging activity.

Example Game Features in Learners' Games. In addition to not experiencing the location-based functionality of the example game possibly affected their understanding of ARIS, almost every game in this workshop did not include location features. Samantha's, the participant who felt like the example game needed to be played outside, game was the only game out of eight that used location capabilities to the point where she actually went outside twice to playtest how the player would have to walk around to play the game. In previous ARIS workshops, learners played example games outside and every game produced utilized ARIS's location capabilities. The lack of location in this workshop connects with the fact that we played the example game inside where the learners were not exposed to location capabilities of ARIS meaning they did not walk around to experience the example game. This hindered their ability to use a key affordance of ARIS, which is location, possibly because they did not understand it due to the fact they did not experience it during the example game.

In addition to the example game playing a role in the lack of location used in learners' games, we also saw that the example game played a role in what ARIS game objects learners used in their games. Specifically, the example game used an ARIS game object called events, which is a way to give to or take away from the player's inventory. Events were present in six of the eight games that were made. For example, Lucy used events to reward the player with medals, "And then, later in the game, you have to save people from supposedly burning buildings, and then you get certain, um—like a bronze

medal or like a silver medal or something like that" (Interview, February 5, 2018).

Samantha used events to take items away from the player, "And you can only have, um, two dogs and three cats in your inventory at one time, and you have to walk and deliver them to the plaque, the adoption center where you deliver them" (Interview, February 5, 2018). The use of events is particularly interesting because they have not been introduced or used in example games in previous workshops and have not been prominent or even used in previous learners' games. If the example game can better incorporate all ARIS game objects, learners can be better exposed to the ARIS constraints and use them to make their games the way they envision them. If we had not used events in the example games, most of the games in this workshop might have not turned out the way they did.

In this workshop, we found that the location-based-ness of the example game played a role in the learners' understanding of ARIS. Hence, it is critical this activity is done properly so learners can experience how location works in an ARIS game. Second, we found that the learners draw ideas from features of the example game, so it is important, especially in a classroom setting, to create example games in line with certain requirements whether they are content or feature-based. This will help prime learners if they begin to think about their own game ideas based off the example game.

ARIS Game Objects Discussion

The goal of the ARIS game objects introductory discussion activity was to familiarize learners with the ARIS interface before they began the debugging activity. For the ARIS game objects discussion, learners sat around a television screen that mirrored the web-based ARIS editor from my computer. I went through the different ARIS game objects that were used in the example game and called on learners who were

in previous workshops to describe what ARIS objects were in addition to asking learners to explain how they could use the ARIS game object after I explained it.

While learners were not explicit about their perspective of this discussion activity, there was still confusion about what ARIS was until the debugging activity meaning this discussion activity did not help to alleviate that confusion. To illustrate this confusion, I'll discuss two learners' comments that describe their first day of the workshop followed by implications based off these insights.

Both of the learners who referred to the ARIS discussion felt that even though they learned about ARIS before going into the ARIS editor, it was still difficult to navigate and understand. For example, Stephanie said, "So we learned about some things, but, um, when you actually get on the computer, you see all of it at once, so it's hard to start, but after that, it's hard to work on too, but having someone there to help is really good" (Interview, February 5, 2018). This mirrored Tina's confusion with ARIS who also was not sure what ARIS was before getting onto the ARIS editor. Tina said, "And, like, you know, you talked about it, but we weren't really sure what it [ARIS] was—or at least I wasn't until we got on." (Interview, February 5, 2018). For both participants, the discussion activity exposed them to ARIS, but they did not fully understand it until they began using the editor during the debugging activity. Hence, the discussion activity did not effectively alleviate their confusions like it should have. This discussion activity has trade-offs of being a direct way to teach learners about the ARIS game objects through a lecture-style approach, but it might not the best way for the learner to fully grasp these ideas because it was ineffective at helping these learners better understand ARIS. These learners' comments support the need to get learners into ARIS sooner after the example

game. Learners could get into ARIS sooner by melding the debugging activity with the

ARIS discussion. Then, learners would go from the example game straight to the ARIS

editor and would be directly applying what they are learning to fix the bugged version of

the example game, which would help alleviate confusion about what ARIS is sooner.

Debugging Activity

The goal of the debugging activity (Figure 12) was to get learners navigating the

ARIS interface and learning more about the logic in ARIS while also learning the unique

ARIS debugging process. Because ARIS is played on an iOS device, learners debug their

games by making edits on the web-based editor and then refreshing the unpublished

version of the game on their iPad to see if it works as intended. For this activity, learners

were in pairs because we thought having two people working on debugging a game could

be helpful. We paired the learners who had already participated in an ARIS workshop

with someone who was new to ARIS. Once paired up, the learners logged into ARIS and

accessed the "bugged" version of the example game. Each pair had two iPads, so they

could easily see the working game and the bugged game. With help from facilitators, the

pairs explored bugs in the ARIS logic to make the game work again.

Figure 12. Participants in pairs for the debugging activity.

Findings for the debugging activity include what the most challenging part of the debugging activity was, which were the locks, and that the debugging activity successes currently fall on a continuum where some learners expressed that the activity was slightly helpful in them understanding ARIS and other learners explicitly reported better understanding of specific aspects of ARIS. To better understand how the debugging activity influenced learners' computational making process, I will illustrate how the debugging activity was both challenging and successful for learners and implications these findings have for future implementations of the debugging activity.

Debugging Lock Challenges. Learners' challenge with the debugging activity was the types of bugs they were fixing, which were logic, or lock, bugs. Figure 13 provides an example of what these types of bugs looked like in the ARIS editor. To fix the bug in Figure 13, the learner would need to select the 'Litter game' game object in the starting scene (left), open the locks editor for this object, and then fix the logic in the locks editor (right).
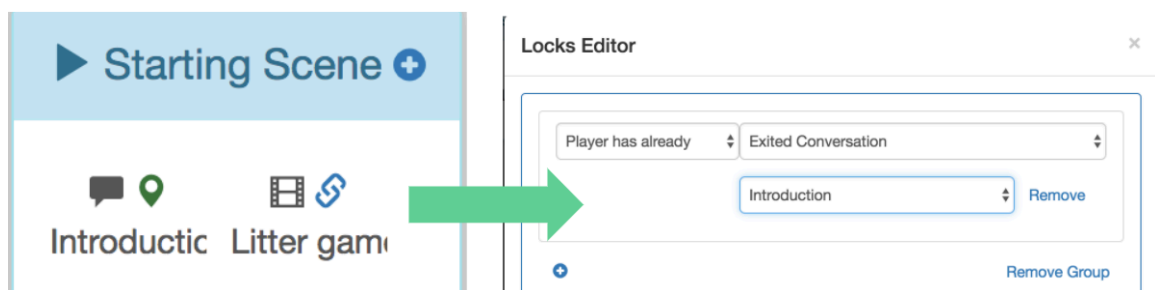
Figure 13. An example of what a bug in the debugging activity looks like in the ARIS editor.

Lock problems were the only type of bugs because we wanted to emphasize the importance of logic in ARIS, which has historically been a difficult concept for ARIS

learners. Instead, this seemed to be ineffective since several of the interviewed learners expressed difficulty with the activity and some even expressed specific challenges with figuring out logic. For example, Sally stated that she "didn't really understand the locks very well" after the activity (Interview, February 5, 2018). Lucy said the biggest challenge was locating which ARIS game object "needed a lock and which one didn't" (Interview, February 5, 2018). In order to find the lock bug, learners had to open the lock editor for each ARIS game object, which can be difficult to navigate for the first time. Sarah expounds on this saying, "Um, I didn't know where to find anything because it was my first time using ARIS," and that "there were too many things happening at once" (Interview, February 5, 2018). Tina felt that actually getting onto the computers for the debugging activity was "a little overwhelming to see all of it at once" (Interview, February 5, 2018). The fact that the bugs were then one of the historically most difficult concepts for learners to understand, locks, did not help with this overwhelming feeling.

Each bug for the debugging activity was a logic, or lock, type bug. This was ineffective since several learners did not understand ARIS logic, or locks, afterwards or were overwhelmed with the interface without even adding the activity of finding logic problems. This is important to know because this activity could potentially become a quicker way to onboard learners onto ARIS but only if we can fully understand how to facilitate a learning-through-debugging activity that supports learners without overwhelming them.

Debugging Success Continuum. While the debugging activity was generally "overwhelming" for learners with some learners even reporting that they still did not understand logic, or locks, afterwards, there were promising pockets of successes, which

fall on a continuum. This continuum ranges from learners who expressed clear ways the debugging activity helped familiarize them with ARIS to learners who provide generalities that suggest the debugging activity was helpful but could benefit from improvements.

On the one end of the continuum, we have learners like Samantha and Stephanie who clearly state how debugging helped them. For example, Samantha says that the activity helped her learn about locks. She said, "It showed me about locks and stuff and how they work, so it's helping me know how ARIS works so I can make my game better suited for it" (Interview, February 5, 2018). Stephanie added to this saying debugging was helpful because "we learned how important locks were and scenes" (Audio, January 29, 2018). Both Samantha and Stephanie are examples of how the debugging activity can successfully support learners' understanding of specific ARIS concepts like locks and scenes.

On the other side of the continuum, learners who expressed challenges and confusion with the debugging activity still commented on how it also helped familiarize them with ARIS. For example, Sally said, "Um, after I did it, I kind of understood it" (Interview, February 5, 2018). Sarah, who also thought the debugging activity was difficult because it was her first time in ARIS making it hard to navigate the interface, reported that she was "a little bit" more familiar with ARIS afterwards but that she still didn't know where anything was and had a hard time remembering the next week when we met again for the workshop (Interview, February 5, 2018). Sally and Sarah are examples of learners who had challenges with the debugging activity but still expressed some value of the activity helping them become more familiar with ARIS.

The debugging activity played a role in these learners' computational making process by familiarizing them with ARIS and for some learners, like Samantha and Stephanie, even explicitly understanding specific ARIS game object, which is the goal of this activity. These successes currently do fall on a continuum that ranges from clear success to less clear success for learners who had challenges with the debugging activity.

These findings support the need to implement changes, which include: 1) diversifying the types of bugs, so the learners are fixing logic problems but also other types of problems, which could help mitigate feelings of being overwhelmed and 2) adding additional design scaffolds to the activity to guide the learner as they navigate the ARIS interface for the first time. These changes could help those who did not experience clear success in the debugging activity by addressing the challenges they had.

Storyboarding

The goal for the storyboarding tool is to help learners begin to think about their game idea within the constraints of the ARIS platform. Storyboarding took place after the introduction activities described above. After giving the learners the workshop prompt, which was to create a game that inspired others to be good citizens or that depicted a local issue they cared about, we discussed what storyboarding is and how it could help them develop their idea. Learners then used the redesigned ARIS storyboarding cards, markers, tape, and large paper to begin mapping out their idea.

Through our data analysis, we found that the storyboarding process was different for each learner. Some embraced storyboarding while others resisted the process or simply did not storyboard. Even though each learner had a different storyboarding process, we also found that this tool was able to help each participant who used it with

ideation, or developing their game idea, and reconciliation, or thinking about how that idea will be built with ARIS game objects, which are the main goals for this tool. I will discuss the storyboarding process for each of the learners who were interviewed to show the variety between their processes as well as the learner who did not participate in storyboarding (and was not interviewed) to show the breadth of processes in this workshop. Following this, I will show how each learner who was interviewed was successfully able to use the storyboarding tool for both ideation and reconciliation support.

Storyboarding Approach One: No Storyboard. Of the eight games that were made, only one participant did not do any storyboarding for their game. The participant who did not do any storyboarding was not formally interviewed because detailed information about why she chose not to storyboard was collected through a discussion recorded on an audio recorder. In addition, because she did not use the storyboarding tool, she would not have been able to answer questions about how the tool did and did not support her computational making process. During my discussion with her, she said she didn't need storyboarding "because I've had this idea in my head for a long while and I kind of have a bit of a fleshed out idea for it" (Audio, January 29, 2018). She further explained that she would use storyboarding if she had a "bigger project." This learner was not adverse to storyboarding but felt that she had already thought about the idea enough that she could immediately start in ARIS. She also had previous experience in ARIS. Due to her having this idea "for a long while" and previous experience in ARIS it could be that she believed she did not need the ideation or reconciliation support the storyboard aims to provide. The rest of the learners who will be discussed were

interviewed and participated in some sort of storyboarding process.

        Storyboarding Approach Two: Embrace. The majority of learners who were

interviewed embraced storyboarding, or participated in the process without showing

resistance. I will show each of these learner's storyboarding process starting with Lucy.

Lucy enjoyed storyboarding her idea and described her storyboarding process as:

> "Um, well, the first thing I did was come up with the introduction and how
> to—figured out how to explain what you're gonna do and like what led up
> to it. And then I started working on like the characters and the different
> items that you'd have to collect. And then I started working on more
> conversations like, "Okay, you've done this. Now it's time to do this," and
> so I just like kept going from level to level." (Interview, February 5, 2016)

Her storyboard (Figure 14) used conversation, character, and item cards. She also used

the back of a card to make her own event card because event game objects currently do

not have a corresponding ARIS card. She used multiple conversation cards to represent

one conversation and put numbers on the different cards to represent the order of the

game.
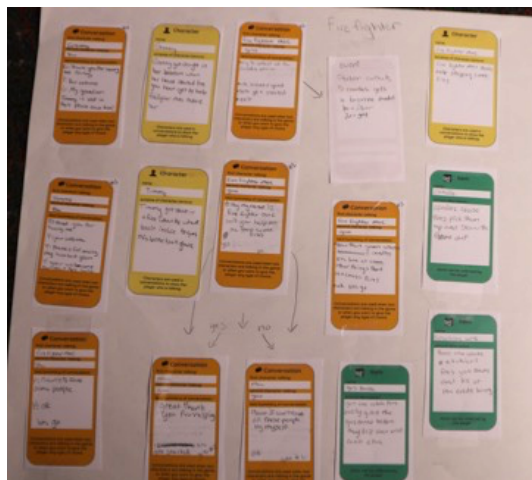
Figure 14. Lucy's storyboard.

Next, Samantha described her storyboarding process as, "Um, I just kind of wrote down stuff I wanted to do, and then I used those little cards to make characters and stuff—and to plan out what I was gonna do, like plaques. Um, like items, factories" (Interview, February 5, 2018). A challenge Samantha had when storyboarding was she "didn't fully understand everything," which was attributed to us only discussing "the basics" (Interview, February 5, 2018). Her storyboard (Figure 15) used multiple cards including item, character, plaque, factory, quest, and lock cards. In addition, she also used markers to write down the plot and goal of her game. Compared to Lucy's storyboard, Samantha's had more writing about her game while Lucy's just used the ARIS storyboarding cards.
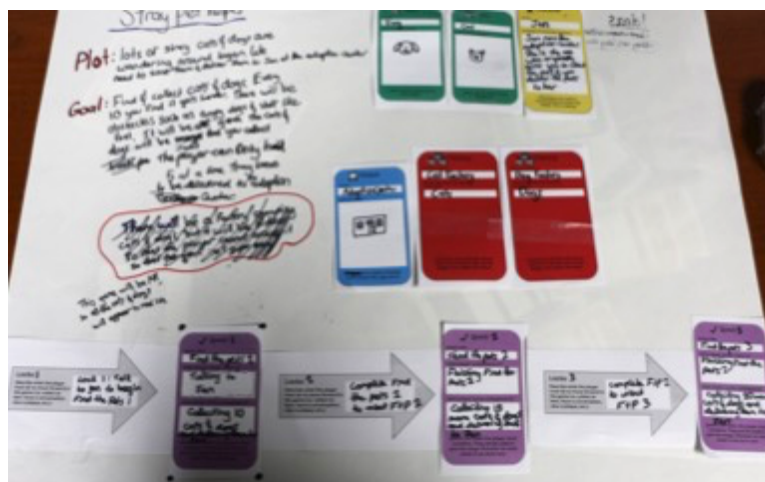
Figure 15. Samantha's storyboard.

Tina and Stephanie both created a storyboard for their one ARIS game, but even working on the same game, they approached storyboarding differently. Tina did not want to use the cards and relied heavily on markers to portray the main conversation in their game while Stephanie only used cards, which is similar to Lucy's storyboarding process.

Stephanie described their storyboards as:

> "So I think that Abby's was more of, um, like, talking to a person what you're gonna do— and mine was more through the program—what we're gonna do. Yeah. Like, I was using the cards we were given—and thinking about how you could really implement in the game—and thinking about how each, um, thing affects what you're creating." (Interview, February 5, 2018).

When I asked Tina about their storyboarding process during the workshop, she said Stephanie's was more of the "boring stuff" and it's "funner to draw it out than to think about how it's going to work" (Audio, January 29, 2018), so there was some resistance to use the cards in this group from Tina. Their storyboards (Figure 16) included conversation, character, plaque, item, and quest cards. There was also a lot of writing and arrows, which represented a conversation, on Tina's storyboard. Like Samantha's board, there was writing, but the writing on Tina's storyboard was for a specific element, conversations, while the writing on Samantha's board was about her game idea in general.
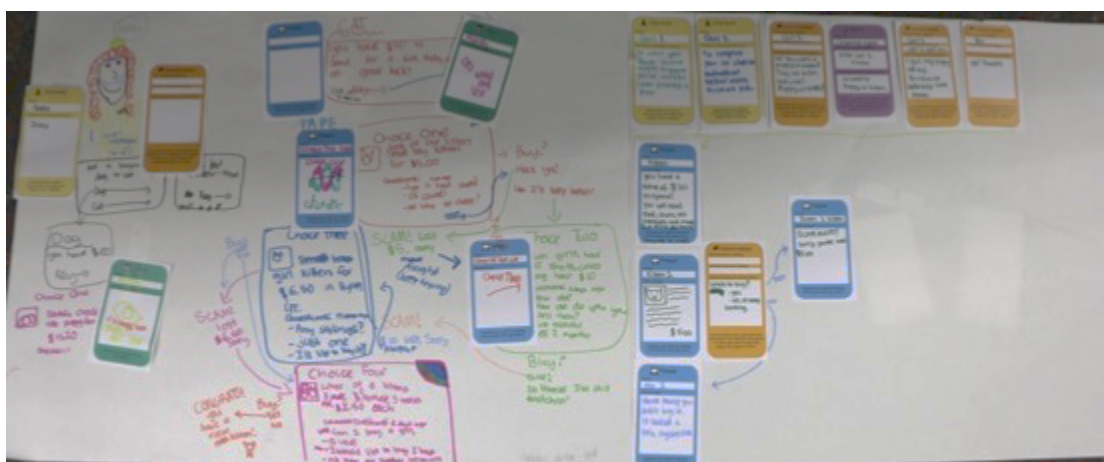
Figure 16. Tina (left) and Stephanie's (right) storyboards for their ARIS game.

Sally began her idea individually. While storyboarding the first day she worked by another participant, who was not interviewed. On the second day, as they continued to storyboard, they worked by each other again. I observed them talking the second day of the workshop and later learned that they had decided to combine their ideas.

> "I go talk to Sarah and Beatrice. I saw them talking to each other when we started storyboarding. They were going to pull ideas from both their games to create one game. Beatrice said they were going to do Sarah's idea and Sarah said she thinks they could combine it. They continued building out Sarah's storyboard and didn't use Beatrice's anymore." (Field notes, January 29, 2018)

Sally described her process saying, "So before, I was just writing down ideas, like how I wanted the game, and then we decided that we started needing to put it more in order" (Interview, February 5, 2018). Her (and her partner's) storyboard (Figure 17) ended up having a front and back side. On the front side, the ideas were written out and on the backside, the order for the game was represented. Her storyboard used item, character, conversation, and quests cards along with writing that outlined the game idea and numbers that represented the order on the back side of the storyboard. Sally used numbers by the storyboarding cards to represent her game's sequence, which is similar to how Lucy displayed order on her storyboard. Also, like Samantha, Sally's storyboard incorporated writing about her general game idea. Even with these similarities, Sally's storyboard still expanded on her game idea differently resulting in a storyboard that is organized and looks different.
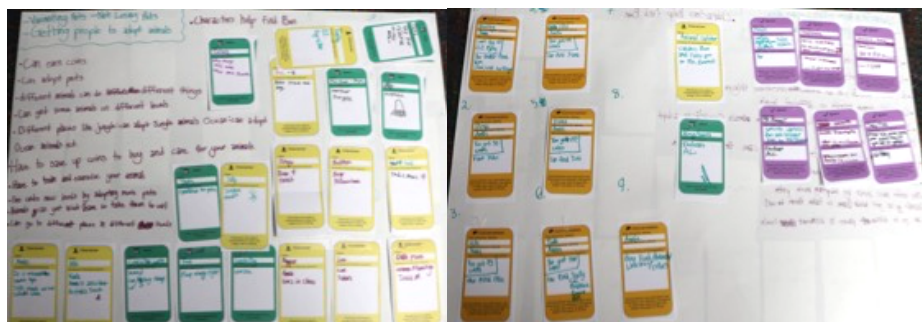
Figure 17. The front (left) and back (right) of Sally's storyboard.

Storyboarding Approach Three: Resistant. Of the six participants who were interviewed, Sarah was the most resistant to storyboarding. On the second day of the workshop, I wrote in field notes, "She tells me that storyboarding isn't really for her. I encourage her to do what will be helpful for her and she responds 'not very much.'" (Field notes, January 29, 2018). Later, in her interview, she again voiced her resistance to storyboarding, "I thought it was, like, a waste of my time because I knew I wouldn't use it for that much, and so it was hard to, like, keep myself working on it" (Interview, February 5, 2018). Even with this apparent resistance though, she continued to storyboard and used her storyboard. She described her process as:

> "Um, well, first, I was drawing boxes, and that took, like, forever. And then whenever there were conversations, I had to branch off and make more storyboards, and I had to keep all of my ideas straight in that one. And so I was like, no, this is too complicated, so I decided to do an entirely different game using quests and, um, gems and stuff. And then, um, once I had an idea that was a good idea, um, I I storyboarded that, and then, um, once I finished storyboarding it, I got into ARIS, looked at it a few times, then completely abandoned and didn't do it." (Interview, February 5, 2018)

Even though Sarah claims to have abandoned her storyboard, I observed her continue to use her storyboard by writing lists on it while programming in ARIS. "Sarah has a list of things to do on her storyboard with checkmarks. She says that is the only reason she uses

paper, to make lists" (Field notes, January 29, 2018). Like Sarah described in her process, her storyboard (Figure 18) has two different ideas depicted on it. The first idea (top) was developed only with marker. The second idea (bottom) used item, quest, plaque, character, and conversation cards. Her list made with marker can also be seen in the middle of the storyboard. Sarah's storyboard also used numbers to show order. Her storyboard is unique because it has two different game ideas displayed on it.

Figure 18. Sarah's storyboard.

The learners in this workshop either did not storyboard, embraced storyboarding, or were resistant to storyboarding. The learners discussed here who either embraced or resisted the tool were able to use this versatile, non-digital tool for their unique storyboarding processes. In addition, even with such differences between storyboarding processes this tool helped each of these learners: 1) develop their idea and 2) reconcile that idea in ARIS, which are the main goals of the storyboarding tool.

Ideation Support. Ideation support, or development of ideas, represents how the tool was able to help participants develop their idea, which is important because the computational making process is also a design process, so there needs to be an idea development phase before learners begin programming. I will show how each of the

learners who were interviewed were able to use this tool to develop their ARIS game idea. For instance, Lucy said storyboarding was difficult as first, "I had all these ideas at once…so the hardest part was trying to figure out how they were connected and how make it flow easily from one to the next, instead of having it confusing" (Interview, February 5, 2018). Even with this challenge, being able to storyboard these ideas helped her develop them because she had a place she could remember ideas and begin to think about them chronologically. She explains that it helped her remember saying:

> "cuz sometimes you have like a rush of ideas all at once, and so, if you write 'em down then…you can go back through and like correct spelling errors or something and make it better, instead of having to think, 'Okay, I've gotta have this idea first, but, oh, what was my other idea? It was so good!' And you completely forgot." (Interview, February 5, 2018)

She also says, "And then I started working on more conversations like, 'Okay, you've done this. Now it's time to do this,' and so I just like kept going from level to level" (Interview, February 5, 2018). In addition, she added numbers to her storyboarding cards to represent the order of her idea. Through the storyboarding tool, Lucy was able to overcome the challenge of figuring out how to connect all her ideas.

Sally's, the participant who decided to meld storyboards with another learner as discussed above, only challenge while storyboarding was writing all the character ideas they had down. She overcame this by using the card to just write the character name down. Besides this, the storyboard helped her develop her idea by providing enough space to "just get all your thoughts down, so it was easy to have your story right there" (Interview, February 5, 2018) and to let her ideas grow. Her ideas grew to include the order of the game. She explains this saying:

> "So before, I was just writing down ideas, like how I wanted the game, and

then we decided that we started needing to put it more in order. And so then we started doing the numbers so that we could decide what character was gonna come first, what they were gonna do. And so that helped, having the numbers that we could see and what order it was gonna go." (Interview, February 5, 2018).

The storyboard tool also helped her ideas grow to add additional features to her game. Sally said, "Um, when I started storyboarding it, um, it was basically you just go along adopting pets, but then we have more of a plot to the story where, um, every time you find a pet, you have to solve a riddle or solve a problem" (Interview, February 5, 2018). Writing down all her ideas may have been difficult, but the storyboard was able to help Sally develop her game idea by giving her a space for her ideas to grow.

Tina and Stephanie had challenges mixing their ideas together and thinking about how their game would work. Tina said the storyboard helped them because "it's a lot easier when you're doing it on the paper because you can plan out what you want on your game" (Interview, February 5, 2018). Stephanie added that storyboarding helped them get the idea. "When I started storyboarding it, the idea really came" (Interview, February 5, 2018). Both Tina and Stephanie were able to use the storyboard to not only think about what their idea would be but plan that idea out.

Samantha's biggest challenge while storyboarding was not fully understanding ARIS because we had only "gone over the very basics" (Interview, February 5, 2018). It was still easy for her to write down her ideas and use the cards to organize her ideas. Looking at Samantha's storyboard (Figure 15), she used the storyboard to outline her idea with writing and then develop details about the idea with the cards. While she didn't fully understand everything about ARIS, this did not stop her from being able to develop the goal and plot of her game using this non-digital tool.

Lastly is Sarah, whose biggest challenge with storyboarding was that she did not find it useful. Still, she was able to use this tool to explore two ideas before beginning to program in ARIS even though she claimed to "abandon" storyboards after making them. Sarah noted that writing her ideas down "catalogues" it into her mind (Interview, February 5, 2018). Because of the freedom of the storyboarding tool, she was able to draw out her ideas, instead of write them out, which she said helped her continue to storyboard. She said, "And so I would, like, draw on it and, um, that would make me still want to do it" (Interview, February 5, 2018). Even with the participant who was the most resistant to storyboarding, the freedom of the non-digital tool helped her to develop and explore two game ideas.

For each of these participants, this non-digital storyboarding tool helped them develop their game idea through their own unique process. This greatly affects their computational making process by allowing them to use an easy interface (paper and writing utensils) to develop ideas before programming them.

Reconciliation Support. Storyboarding also helped learners reconcile their game idea, or think about how their game idea will be programmed in the digital editor using ARIS game objects. This is important because it prepares learners for the development phase of the design process. I will discuss how each of the interviewed learners exhibited reconciliation support. First, Lucy stated that she looked at her storyboard while building in ARIS. She said, "Um, I got past the first scene pretty quick cuz I had a good outline of what came first and then what came next, and exactly how they were outlined." (Interview, February 5, 2018). She further explained that she used her storyboard as a base but was able to keep building on it:

"Um, I looked at it and thought how I could maybe improve it, but still keep the basic idea. I—so I looked at like the basic outline of my conversation or something. Like my intro is a conversation, so I would look at the outline and like see what it says, and then I'd be like, oh, maybe I could change it to say—like make more sense, and then could have options. Cuz when I came up with the ideas, I just wrote down like the simple guideline…" (Interview, February 5, 2018)

While Lucy was programming in ARIS, she was able to refer to her storyboard to help her bring her ideas from the storyboard into ARIS. In addition to bringing her ideas from her storyboard into ARIS, she was also able to use the cards to know which ARIS game objects to use. While she didn't explicitly talk about this in her interview or during the workshop, cards on her storyboard align with game objects used in her final game. For example, the items and event that were on her storyboard were also in her final game.

Like Lucy, Sally talked about using her storyboard as a reconciliation support once she began programming in ARIS. Sally referenced her storyboard as she programmed in ARIS and explicitly said she used the cards to help her know where to go in the editor, "So it definitely helped, having the storyboard there because you could look at your storyboard, and then it also helped to have the cards because it told you where to go, kind of" (Interview, February 5, 2018). In addition to helping Sally know where to go in the ARIS editor, the storyboard also helped her organize her game within the organization structure of ARIS, which are scenes. "So, um, it helped that, like, I had everything in order already, so that helped with the scenes because I knew which should be the scene, which should be the second scene, and so on" (Interview, February 5, 2018). Sally referred to the order of her storyboard, and the cards on her storyboard to help her reconcile her game idea in ARIS.

Tina and Stephanie started storyboarding with differing opinions about the use of

the ARIS storyboarding cards. Tina referred to them as "boring." She did not want to be thinking about how their game would be working. On the other hand, Stephanie used the cards to begin thinking about how their game would work in ARIS while they were storyboarding. Stephanie said:

> "Like, I was using the cards we were given and thinking about how you could really implement in the game and thinking about how each, um, thing affects what you're creating so everything on your paper—on my paper was more, um, set up in the way that ARIS is." (Interview, February 5, 2018)

Later, Tina even appreciated having Stephanie's cards because this helped as they progressed to the programming part of the computational making process. She explained this saying, "Well, we knew what we wanted and Stephanie had the how we were going to do it, so I don't think it was as hard as it would have been if we didn't have the—her technical part" (Interview, February 5, 2018). Stephanie began using the storyboard as a reconciliation support while they were developing their game idea. Later, both Tina and Stephanie referred to Stephanie's storyboard to help them know how they would create, or reconcile, their game idea in ARIS.

Samantha also began thinking about how she would make her game in ARIS while she was developing her idea. She explained her storyboard as a "plan" for what she was going to do, and "a basic layout for what I wanted to do and showing all the different components I wanted to include in my game" (Interview, February 5, 2018). Then as she began to program her game in the ARIS editor, she referred to her storyboard to help her build her game saying that "it was pretty easy, changing them from cards to things on ARIS" (Interview, February 5, 2018). As Samantha developed her idea using the ARIS storyboarding cards, she was able to do more than develop her idea; she also began

planning how her game would work in ARIS by thinking about the "components" she would be using in the ARIS editor. Like the other participants thus far, she was then able to refer to her storyboard to help her know which ARIS game objects to use to build her idea.

Lastly, even Sarah who did not value the storyboarding process as much as the other participants, used her storyboard as she began programming her game in ARIS. Sarah explained that her storyboard helped her start in the ARIS editor:

"Um, well, I looked at it a lot at first, and so, like, it started me off, so I knew what I wanted to do at first. And then as the game got more and more developed, I, um, started, like, memorizing the storyboard from looking at it so much so then I could, like, put it into the computer immediately." (Interview, February 5, 2018)

Sarah stated that transitioning from her storyboard to the ARIS editor was easy, and she was able to do it with "not very many problems" (Interview, February 5, 2018). Sarah does not specifically say that the ARIS storyboarding cards helped her know what game objects to use in ARIS, but her item and quest cards on her storyboard align with her final ARIS game. This plus her stating that she referenced her storyboard then tried "to figure out how to do it on the computer" could imply that she was able to refer to her cards to help her know how to start building her game in ARIS.

Each of these participants used the storyboarding tool to help reconcile their game idea in ARIS. This has a positive impact on their computational making process by helping them spend less time figuring out how to translate their idea to the tool and more time programming their idea.

Even though each learner had a different looking storyboard and storyboarding process, this tool was still able to help with ideation, or developing their game idea, and

reconciliation, or thinking about how that idea will be built with ARIS game objects, which are the main goals for this tool. This non-digital storyboarding tool was able to act as an "object-to-think-with" for these participants as they progressed in their computational making process and furthermore, affected their process by helping them form their idea within the constraints of the ARIS platform.

STUDY TWO: DESIGN SCAFFOLDS EVALUATION

My research question for Study Two is an evaluation question where I address the effectiveness of the changes I made to the introduction activities and storyboarding tool prior to data collection. To do this evaluation, I used the ARIS designer interview data. In addition, these findings build on what was found in Study One by using Study One insights to inform the evaluation

In the following section, I will provide details about the ARIS designer participants and the data collection and analysis processes. Following this, I will discuss the findings that resulted from this analysis.

Participants, Data Collection, and Data Analysis

ARIS designers are those who have intimate experience with the ARIS tool because they have been part of at least one of the following: 1) the design of ARIS either through interface design or the actual programming development of the tool, 2) the design of ARIS experiences for clients that include building ARIS interactions for both informal and formal learning environments, and/or 3) the facilitation of ARIS computational making experiences for either youth and/or adult learners.

Participants and ARIS designer interviews

Five ARIS designers consented to be interviewed (5 male). The ARIS designers that were identified for this study work at the Field Day Lab at University of Wisconsin – Madison, where ARIS was first created and is still maintained. They have multiple years of experience with ARIS in one of the capacities described above. Their insights were sought after to evaluate the introduction activities and storyboarding tool as well as get suggestions for improvements. Their experience with designing ARIS games and

facilitating ARIS workshops was an available and invaluable resource that needed to be drawn on to follow a truly systematic process that included all the data that was available to me for this inquiry.

Data Collection

I traveled to the University of Wisconsin – Madison Field Day Lab to hold semi-structured interviews (Appendix B) with four of the five ARIS designers. I completed the fifth designer interview via a telephone conversation. Five designers (Table 4) were used because that included all the employed designers currently at the Field Day Lab and, like I described above (refer to Study One section), getting the insights from five would provide enough information needed to better understand what changes could be made to the tool.

Before showing the redesigned introduction activities and storyboarding tool to the designers, I asked questions about challenges learners face and expectations the designers had for the scaffolds. Following these questions, I gave a detailed explanation of the introduction activities and storyboarding tool. I also had a detailed outline of the introduction activities and all the materials that made up the storyboarding tool that they could refer to during the interview. The remaining questions aimed to get their feedback on the introduction activities and storyboarding tool as well as their insights on how these scaffolds might help or not help learners going through a computational making process within ARIS. All interview data was uploaded and saved on Box.com to comply with security and confidentiality regulations.

ARIS Designer's Pseudonym	ARIS Designer's Role
Tony	ARIS Game Developer, Designer, and Facilitator
Ted	ARIS Designer and Facilitator
Wyatt	ARIS Designer
Scott	ARIS Game Developer, Designer, and Facilitator
Adam	ARIS Game Developer and Designer

Table 4. ARIS designers' pseudonyms and ARIS roles.

Data Analysis

To answer my second study's research question, I used all the interview data from the five ARIS designers. The undergraduate researcher and I used a qualitative software called Dedoose to create a coding scheme, which was developed through open coding methods. A summative version of our codebook can be referenced in Table 5. The open coding process started with the first round of open-coding where the undergraduate researcher and I used both descriptive and in vivo codes (Saldana, 2009). I open coded all five ARIS designer interviews while the undergraduate researcher open coded two due to time constraints. Following this first round of coding, I reviewed all the descriptive and in vivo codes and began to create pattern codes (Saldana, 2009). Before using these pattern codes in the second round of coding, the undergraduate researcher and I met to make sure the codes from round one were well represented and to create definitions for each of the pattern codes. These pattern codes were then used in the second round of coding to analyze the interviews. To begin the second round of coding, we each coded the same

two interviews the undergraduate researcher coded in the first round of coding. This was

so we could then discuss the codes we applied and participate in a consensus coding

(Saldana, 2009) process. Through discussion, we were able to reach consensus, or

agreement, on the codes for two out of the five ARIS designer interviews. Following this,

I finished the second round of coding by applying the pattern codes to the final three

interviews. In addition to this open coding process, our coding scheme was also informed

by a user experience framework (Miki, 2014), which I discuss below.

Designer Codes	Code Definitions
Designer storyboard goals	Designer perspective on storyboard tool goals/what this tool should do during the process
Designer process goals	Designers perspective on what the process should do
Designer storyboard strengths	Designers refer to a part of the tool as strong or good
Designer process strengths	Designers refer to a part of the process as strong or good
Designer feedback	Improvements to the tool or process and general feedback/insights from the designers
Designer strategies	Techniques designers used to introduce ARIS in the past or suggest should be used
Context	When designers refer to context (goals of the situation/learning environment) as important
Challenges	Problems with the ARIS tool

Table 5. A summative codebook for the ARIS designer open codes and definitions.

Use of User Experience Evaluation Framework for Analysis. The user

experience evaluation framework (Miki, 2014) focuses on the user's needs and integrates

the International Organization for Standardization's (ISO) usability model (International

Organization for Standardization, 1998) with user experience constructs (Miki, 2014).

ISO's model evaluates usability, or "extent to which a product can be used by specified

users to achieve specified goals with effectiveness, efficiency and satisfaction in a

specified context of use," (International Organization for Standardization, 1998). Miki

(2014) integrates this model with constructs of user experience to capture the users'

subjective "perceptions and responses" before and during the use of a product. Miki

(2014) introduces four new constructs to the model: 1) perceived value, 2) perceived

quality, 3) complaint, and 4) loyalty while adjusting intended/expected goals to intended

goals/expectations. By adding these constructs, the model now captures more than when

the product is being used; it also captures before and after the product is used with

expected goals, complaint, and loyalty. In addition, by adding subjective measurements,

the model can represent the users and their voices as much as possible.

To use this evaluation framework for analytical purposes, I attempted to adopt the

definitions for the following constructs in my codebook: goals, expectations,

effectiveness, perceived quality, perceived value, satisfaction, and complaints. I found

that these definitions were not specific enough for my context. I planned to exclude the

loyalty construct because this measurement deals with likelihood to purchase the product,

which is not relevant to my context since ARIS and these design scaffolds are free to use.

We discovered, however, that the original definitions the user experience

evaluation framework used were too vague and/or ill-suited for our data. Therefore, we

instead used the framework to inform the open coding process instead of adopting the

definitions word-for-word into our codebook. Even though the exact definitions of this

framework were not used, I still claim that the definitions are being represented in my open codes. To support this, I will explain how each code I intended to use is represented in my codebook (Table 6). Goal and expectations are represented by the codes storyboard goals, process goals, and designer strategies because these codes account for what the designer believed the introduction activities and storyboarding tool should do to help the learner (goal) prior to the designer being exposed to the introduction activities and storyboarding tool (expectations). Effectiveness, efficiency, satisfaction, perceived value, and perceived quality are all represented with designer storyboard strengths, designers process strengths, and context because these codes capture how accurate the designer believes goals are achieved within specific learning settings (effectiveness), how the resources could affect the learners' process (efficiency), when designers showed positive feelings towards the tool or process (satisfaction), and their perspectives on the worth of the introduction activities and storyboarding tool (perceived value) as well as how well the tool could meet learner needs (perceived quality). Lastly, complaint is represented by the code designer feedback because this code shows when designers had problems or concerns with the introduction activities or storyboarding tool. These problems also help identify what changes should be made.

User evaluation codes	Designer Codes
Goal, expectations	Storyboard goals, process goals, designer strategies
Effectiveness, efficiency, satisfaction, perceived value, perceived quality	Designer storyboard strengths, designer process strengths, context
Complaint	Designer feedback

Table 6. The codebook code(s) that will represent the user evaluation code.

Findings

To answer Study Two's research question, I used the ARIS designer interview data to evaluate the changes that were made prior to data collection. In addition, these findings build on what was found in Study One by using Study One insights to inform the evaluation. Below, I provide an evaluation for the introduction activities and the storyboarding tool, which includes the goal and feedback for the design scaffold as outlined by the ARIS designers. As a result of these findings, there are also suggested changes for how the introduction activities or storyboarding tool could be improved.

Introduction Activities Evaluation

The introduction activities being evaluated include the example game, ARIS discussion, and the debugging activity. To evaluate these activities, I will first describe what the ARIS designers expected from the introduction activities and then their insights on the effectiveness of each activity, which will provide the evaluation.

First, Scott, an ARIS designer, provides a clear description of what these introduction activities should do for the learner. These activities should work together to build a "mental model" of ARIS, which Scott, an ARIS designer, described as the biggest challenge ARIS learners face. He said:

> "And so the biggest challenge is getting people to—and I think the most important challenge, again, in my experience, is getting people to have this mental model of this structure in their head of, okay, well, an ARIS game is comprised of these types of things that interact with these types of things in these types of ways." (Interview, January 31, 2018)

Other experts reiterated challenges of terminology and understanding what a location-based game means, which also speaks towards the importance of building this mental model of what ARIS is for the learner. This mental model includes knowing what

location based means, ARIS terminology, and how different game objects work together to create an ARIS game. By helping build this mental model of what ARIS is instead of just telling learners what to do, the learners can begin to develop their own ARIS game ideas within this mental model. Supporting the development of this "mental model" is the goal for the following introduction activities.

Example Game. The example game and ARIS discussion about the example game are the first effort to begin building this mental model. The ARIS designers responded positively to this scaffolding strategy. Wyatt, an ARIS developer, said playing and discussing an example ARIS game could help overcome terminology challenges and be a successful way to introduce learners to ARIS. He explained:

> "I—probably, um, the best way that I can think of to get over those kinds of hurdles is—is, I think, through like seeing example games and, uh, like explaining how—or you're showing some kind of like logic or—or flow— through the—the game with showing it, and then explaining, like, this is— these are the different pieces that—that make that happen—and showing like the—the—the locks necessary or the, um—the whatever—wh— whatever pieces make that—that logic happen." (Interview, January 31, 2018)

Wyatt supports the use of an example game and its ability to expose learners to the terminology and logic that ARIS uses. In addition, Ted expresses the need for "being out in the field" when creating GPS based games (Interview, January 31, 2018). An example game is also a good way to expose learners to what a location-based game looks like especially because the idea of creating a story that uses location might be novel to ARIS learners. Ted's thoughts build on the importance of using the example game to expose learners to location-based functionality that was found in Study One. Lastly, Scott's explicit evaluation of the example game activity was:

Um, but playing the game is—it—it kind of fills that gap to a degree of like what composes an ARIS game, of like building that, you know, mental image of, um, you know, the limitations and the structure of an ARIS game. Okay, I'm on a map. There are these things that I go to. You know, so that's already a huge good start, and it avoids the [laughter]—the just top-down lecturing. Um, so I thought that was really good." (Interview, January 31, 2018)

Overall the use of an example game made sense to the ARIS designers as a way to begin building a learner's "mental model" of ARIS. This designer evaluation of the example game helps to support its use as a design scaffold. The evaluation does stress the importance of the game including logic and exposing learners to the location based functionality of ARIS, which was not done well in the workshop we held. In order to really begin creating a mental model, future uses of the example game need to be played outside or in large spaces, so the learners experience the location based functionality. This is a change that is supported by both ARIS designer and learner data that must be made to the example game introduction activity.

ARIS Game Objects Discussion. ARIS designers supported the use of an ARIS discussion but also provide valuable insight about why these introduction activities can be confusing for learners, which aligned with findings from Study One. Even though the ARIS designers supported this activity, these insights still promote the combination of the ARIS discussion with the debugging activity, which I show why below.

Above, Wyatt explained the importance of pairing the example game with a discussion of the example game (Interview, January 31, 2018). Scott also shared that in the past this interactive ARIS discussion has been used and that the example game sets the stage for a more interactive discussion about ARIS game objects (Interview, January 31, 2018). More importantly, Scott further explains that this "mental model" approach is

less straight forward for the learner because the learner might not fully understand why they need to know this information (Interview, January 31, 2018). While the ARIS designers did support the ARIS discussion in their evaluation, Scott brought up a tension of learners not understanding the need for these introduction activities due to the lack of direct application, which we experienced in our workshop.

In our workshop, learners reported being confused about what ARIS was until they began the debugging activity. As a facilitator, I also found the learners' demeanor was low-energy during the ARIS discussion. It seems because of the current complexities and nuances of the ARIS platform that some of these introduction activities, like the ARIS discussion, are seen as a 'necessary evil' that learners must go through to be prepared to enter the ARIS interface. Building on the findings concerning the ARIS discussion from Study One combined with the ARIS designer insight of these activities not being straight forward to the learner, I continue to suggest the melding of the ARIS discussion with the debugging activity. By putting these two activities together, we can create introduction activities that are more straight forward by having learners directly apply what they are learning about ARIS game objects to debug the example game instead of sitting through a lecture-style discussion. In addition, learners will still be building their "mental model" through sooner exploration of the ARIS interface instead of a lecture format.

Even though there was ARIS designer data in support of the ARIS discussion, the insight that these introduction activities are not straight forward for learners aligned with what we found during our own workshop, which supports the need to combine the ARIS discussion with the debugging activity. By implementing this change in future ARIS

workshops, learners can go straight from the example game into the ARIS editor, which could potentially clarify ARIS game objects for learners.

Debugging Activity. The last design activity I'll discuss is the debugging activity, which is a brand-new addition to the ARIS introduction activities. Some ARIS designers supported the debugging activity while others had hesitations. With this mixed review from the ARIS designers combined with the findings from Study One, it is clear that changes need to be made to better debugging activity. These changes include incorporating different types of bugs besides just logic bugs and providing a checklist of bugs learners need to find. I will discuss the ARIS designers' evaluation of the debugging activity and how it supports these suggested changes below.

The ARIS designers ranged in their evaluation and thoughts about the debugging activity. Some felt strongly that the addition of a debugging activity would be helpful in showing learners the ARIS debugging process while others thought the activity could be overwhelming for learners. ARIS designers that were in favor of the debugging activity felt that having it as a required piece is good because debugging always comes up in the ARIS game making process (Interview, January 31, 2018; Interview, February 6, 2018). Scott explained the debugging benefits saying:

> Um, yeah, I—in these workshops, whenever we get to the point where they're like actually making these games, debugging always comes up. Um, in that they're like, "What? This isn't working," and it's—it's always, in every case, just totally paralyzing. Um, so, hopefully, uh—I mean I don't know. I haven't seen anything, but hopefully that debugging section, you know, gives them some agency. (Interview, January 31, 2018)

While the potential benefits of the debugging activity are noted, it was clear that learners found the debugging activity to be overwhelming. Wyatt explained that the debugging

activity could be too much of a cognitive load on learners. He said:

> Um, I guess one of my first concerns would be like, would this take like so much, um—like have such a high of a cognitive load that by the time they actually get to storyboarding, they're like, "Man, I'm kinda cooked from like learning all these new concepts"? (Interview, January 31, 2018)

Wyatt continued to explain that the reason for this high cognitive load from his perspective could be that "debugging someone else's code is awful" (Interview, January 31, 2018) because the learner does not have "stake" in the code that needs to be fixed. The effectiveness of the debugging activity is mixed from both the ARIS designer and learner perspective. On the one hand, the debugging activity is useful because it exposed learners to ARIS in a structured way while also helping them develop their debugging skills for their own game. On the other hand, the debugging activity was difficult for learners due to the amount of logic bugs, which could have made it cognitively overbearing. From both the ARIS designer and learner perspective, this activity needs to be changed to better learners' experiences. Hence, I suggest improving this activity by combatting the difficulties, which are the amount of logic bugs and the high cognitive load. We can do this by diversifying the types of bugs and providing better guidance for the learner in future implementations of the debugging activity.

By diversifying the types of bugs, learners will not just be looking for logic bugs, which were difficult for them. Consequently, this could help reduce the cognitive load of the activity while still exposing the learner to different types of problems they may see in their own game. When implemented, there will still be logic bugs, but there could also be missing ARIS game objects that the game needs in order to progress or a conversation that needs to be built out. The bugs can be guided by the specific requirements or goals of

the ARIS activity or workshop. Secondly, by providing a list of the bugs, the learner will

have some guidance of where to look since it is their first time in the ARIS interface. This

will help them focus on learning the ARIS editor instead of being overwhelmed trying to

navigate it. These changes to the debugging activity all work to make it less

overwhelming for the learner while still providing the benefits of exposing learners to the

debugging process, which will be a major part of their game development process.

Teaching Logic in the ARIS Editor

The last change I am suggesting for the introduction activities would be a

universal change that would affect each introduction design activity. This potential

change is concerned with how to teach logic development in the ARIS editor.

Historically, we have taught logic development in ARIS to use locks on individual ARIS

game objects. Instead, Adam, an ARIS designer, suggested applying logic one level up

from the ARIS game object and instead apply logic to scenes. Adam said:

> I usually think of them [locks] much more, uh, with that kind of, uh,
> scenes—or—or pseudo-scenes mentality of like you would have—that you
> would have like—like, uh, a selection of—of things [ARIS game objects],
> either on the map or that you—that you scan, um, that all together would
> be—have—have some lock in front of them to—to get to them. (Interview,
> January 31, 2018)

Adam continued to explain that a learner might use a lock on an individual ARIS object

instead of a scene if the flow is "more complicated than what can be expressed in like a

linear scene to scene to scene, uh, situation" (Interview, January 31, 2018). For example:

> "if you want to go from a certain set of things is available to that same set,
> but maybe one—one more thing added. Then that—that—that would be a
> situation where you'd—you'd wanna—you—you just want that—that one
> thing to have a lock making it available, rather than having to like duplicate
> everything between the two scenes." (Interview, January 31, 2018)

What is especially interesting about this is when logic is applied at the game object level, the learner cannot see the logic they've applied. For example, on the left side of Figure 19, the learner cannot see what the lock (the link icon) on the 'Bananas' game object does unless they open the lock editor for that game object. When a learner applies the logic at a scene level, a green line appears, which is depicted on the right side of Figure 19. This green line shows the learner the logic, or flow, of the game without them having to open the lock editor.
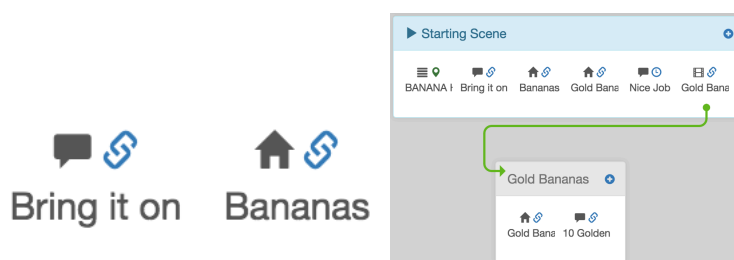
Figure 19. Logic applied at the game object level (left) and at scene level (right).

We have observed learners in previous ARIS workshops use this strategy but have never taught logic this way. Previous observations combined with this ARIS designer evaluation support the suggested change to teach logic on the scene level instead of the game object level, which could make logic, a historically difficult concept for learners, easier since it would be more visible. This change in teaching the development of an ARIS game would be represented and embedded in the example game and debugging activity.

After the example game and debugging introduction activities, learners should have developed a mental model of ARIS. The suggested changes for these activities are meant to better support the development of this mental model, which is necessary if

learners are to storyboard with ARIS storyboarding cards and think about their ideas within the constraints of the ARIS tool.

Storyboarding Tool Evaluation

To evaluate the storyboarding tool, I will first describe the ARIS designers' expectations from this tool. Following this, I will outline the ARIS designers' perspectives on the tool's successes as well as areas they thought could be improved. This evaluation will also provide suggested changes for the next ARIS implementations.

ARIS Designer Storyboarding Expectations. The goals for the storyboarding tool that several ARIS designers shared included the ability for the learner to get their idea "out of their head" and gives learners a way to "bridge" what is in their head with ARIS game objects (Interview, February 6, 2018). Designers also emphasized the importance of the storyboard helping to put an order to the learner's game idea. It was clear that the ARIS designers believed that the storyboarding tool should help learners with ideation and reconciliation, which the storyboarding tool did well for the learners in this workshop. In this section, I will give more details about what the ARIS designers found successful about the tool and the feedback they gave to further improve the tool.

Storyboarding Tool Successes. ARIS designers responded positively to the addition of the lock card. Tony said the card is helpful when helping learners think of sequencing. He said, "And that—that—that makes a ton of sense to kinda say like, here are these moments, and they're separated through these arrows, so we're thinking about sequence over time" (Interview, February 6, 2018). Designers also thought removing some of the information from the ARIS storyboarding cards was good because this information is not necessary during the ideation phase. Scott agreed with this change

because "it's a difficult challenge to portray all the different possibilities on their

appropriate, you know, level of relevancy" (Interview, January 31, 2018). In other words,

displaying every option for ever ARIS game object is not necessary at the idea

development phase. Removing this additional information can help the learner focus on

their idea and not be overwhelmed by ARIS features. Lastly, Wyatt brought up the

success of the storyboarding tool materials, which allowed the learners to freely depict

their ideas because paper is "immediately understandable" (Interview, January 31, 2018).

In addition, the materials made it easy for the learners to put their ideas down in their

own way, which Wyatt said is how "a piece of paper should be used" (Interview, January

31, 2018). While the storyboarding tool was successful overall for both the learners and

designers, the ARIS designers still identified important areas of feedback to consider.

Storyboarding Tool Feedback and Suggested Changes. The first area of

feedback was with the design of the conversation card. Currently, conversation cards do

not accurately represent the conversation game object that is in the ARIS editor. In the

ARIS editor, conversations are made using branching logic, but on the card, the learner is

prompted to write down the text or a summary of the conversation. Designers commented

on the disconnect between the conversation card and the conversation feature in the

editor. Wyatt suggested:

> "Instead of a card that's like, 'This is your conversation,' could be like,
> 'This is where you set up the different parts of your conversation now.' Like
> may—maybe certain cards have like an arrow, or like a—a notch that's like,
> okay, this is meant to spill out onto the paper." (Interview, January 31,
> 2018)

In addition, learners worked around this disconnect by using multiple ARIS cards or by

using markers to draw out their branching conversation structure. The conversation card

should be changed to include prompts such as purpose of conversation and conversation

summary. A notch can then be added to the bottom of the card to signify to the learner

that they could build out the branching logic using writing utensils, which aligns with

how some learners in our ARIS workshop used markers to build out their conversations.

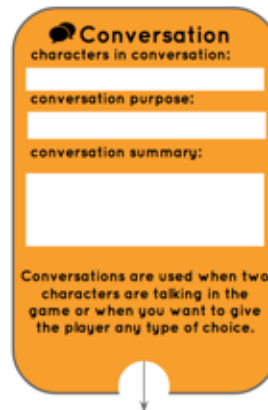Figure 20 depicts the redesigned conversation card with these suggested changes.

Figure 20. Redesigned conversation card informed by ARIS designer evaluation.

The second area of feedback is to restructure the ARIS storyboarding cards. The

restructuring of the ARIS storyboarding cards considers how these cards could be

redesigned to show that each card is different from one another while still showing how

the cards work together to create a game. Wyatt explained this saying:

> "…for like the actual cards, to have like—you can—they can feel very
> similar, um, but maybe to show like that there's like s—they, um—they're
> different. You know, this is a character. This is an item. This is a, um—A
> plaque, yeah. And then this is a conversation. This is a quest. And so what's
> nice is like, if you—if you think of them more like, um, they're like all—
> they're kind of all like puzzle pieces—like of a cohesive UI, but like
> inherently different. Like this is a node that just like spills out, so it—it
> exists within the context of your paper or your whiteboard." (Interview,
> January 31, 2018)

Scott also emphasized the need to redesign the cards to show that each card is different from one another more than just differing the colors already used on the cards. He said:

> "So like character is kind of a sub-idea of a conversation, um, and—Yeah, and, uh, quest is kind of this, you know, overarching, you know, thing that composes these ideas together. So to have like—if you squint your eyes, this looks just like a purple version of one of these." (Interview, January 31, 2018)

For example, an event card does not exist right now partly because events do not behave like the other ARIS game objects. Events can be on their own, but they can also be embedded in other game objects. To show this embedding and system that the ARIS designers are referring to, I suggest a redesign strategy that would incorporate notches in the storyboarding cards to show which game objects work together. An example of this is depicted in Figure 19 where the event game object uses a notch to show it can be embedded in the conversation game object (Figure 21).
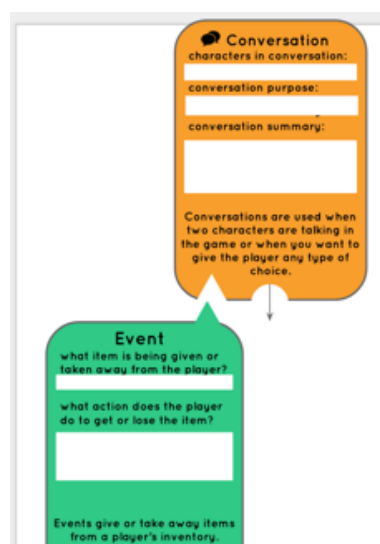
Figure 21. Example of how notches in the storyboarding cards can show what ARIS game objects work together.

Another example of this is depicted in Figure 22 where a factory and an item use both

color and a square notch to show that these two ARIS game objects work together.

Figure 22. Example two of how notches in the storyboarding cards can show what ARIS

game objects work together.

The addition of notches to the storyboarding cards attempt to show what game objects

work together. This strategy mimics block based programming approaches (Figure 23)

where certain programming elements fit into their corresponding element.
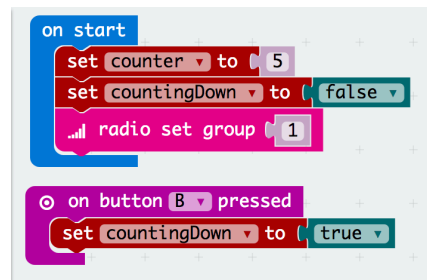
Figure 23. Example of what block-based programming looks like.

A potential concern for this change is how it would impact the printing and cutting of the

storyboarding cards. The addition of the notches, though, doesn't have to change how the cards are printed and cut. They could still be printed multiple to a single page and then cut into squares. The design would still show learners what ARIS game objects connect to each other without the individual notches being cut out.

These suggested changes to the introduction activities and the storyboarding tool come as a result of the ARIS designer evaluation and Study One findings. To see if these changes would result in better design scaffolding for ARIS learners, another iteration of research and user testing would need to be done with learners.

DISCUSSION

In these two studies, I explored how introduction activities and a storyboarding tool could act as design scaffolds for learners engaged in a computational making process using the visual programming tool ARIS. I investigated the effectiveness of introduction activities and a storyboarding tool as learning scaffolds in an ARIS workshop with youth learners. In addition, ARIS designers also evaluated the effectiveness of the redesigned scaffolds. Data from both studies helped identify weaknesses and make subsequent changes to the introduction activities and storyboarding tool.

I explore the broader implications for both studies throughout this discussion. The insights include ways to better transition learners into computational making processes through design scaffolding, tensions that exists between non-digital and digital interfaces, approaches for future research to combat these tensions, and lastly, the broader impact of changes made to the storyboarding tool.

Transitioning Learners into Computational

Making using Introduction Activities

The goal of design scaffolds for computational making are to better support learners engaged with a computational making process. While some scaffolding techniques (e.g., reflection, information processing, computer scaffolding, and facilitation) are used in computational making processes, current research does not focus on such design scaffolds. Thus, design scaffolds for computational making must be evaluated and updated (Lye & Koh, 2014). In this study, we scaffolded learning with introduction activities including an example game, open discussion, and debugging activity. Introduction activities like these are one type of scaffold for computational

making processes to better transition learners into visual programming tools. One broader implication from these introduction activities includes how an example game can prime learners prior to making a game. A second particularly promising broader implication arose from the debugging activity, which familiarized learners with the visual programming tool to develop ideas well suited for the ARIS tool.

Using an Example Game to Prime Learners

Introducing learners to an example game illustrated a game made using ARIS by exposing learners to the game objects used by the visual programming tool to create a game. The example game affected how learners envisioned and created their games. This highlights the need to align example games with the computational making activity content and requirements, especially when implemented in a classroom setting.

Researchers and educators should consider the goals and requirements of a computational making activity while creating an example game. For example, in order to focus our workshop's learners on games about local issues we used an example game about local littering problems. In this way, we exposed learners to a game topic aligned with the workshop topic. In addition, we intentionally used each ARIS game object and incorporated both narrative and game mechanics so learners could see all that ARIS had to offer. If it was more important for learners to create a narrative, we could have adjusted the example game to focus on the narrative instead of game mechanics. These are design considerations for educators and researchers using example games as a design scaffold for visual programming tools.

Debugging as a Pedagogical Tool for Computational Making

The debugging activity was successful in its goal to familiarize learners with the

interface and constraints of ARIS. Broadly, we show that debugging can help familiarize learners with their visual programming tool in order to develop ideas well-suited for the tool. Debugging was also able to reduce time needed to familiarize learners by providing a structured environment for learners to explore and learn the visual programming tool. This reduction was evident in our workshop where learners went through a six-hour computational making process, rather than the typical twelve-hour process. The games from the six-hour and twelve-hour processes had comparable quality.

Promising results from the debugging activity indicates that future research should explore this pedagogical strategy for improving learners' transition into computational making with visual programming tools.

Tensions between the Non-Digital Tool to the Digital Interface

Non-digital tools (e.g., the storyboarding tool) are another type of scaffold used in this thesis to aid computational making processes. We found that paper storyboards allowed learners to more easily and freely organize their ideas without constraints in a digital interface. However, this benefit created issues when transitioning ideas into the digital interface with its new constraints and specific navigation rules. Although paper did not directly translate to digital format, the storyboarding design scaffold was still successful at helping learners outline their idea imagine its conceptualization within the ARIS editor.

The issue of transitioning from paper to digital formats brought up improvements for the digital ARIS interface design to better scaffold learners. For example, steps to guide first time learners through creating an ARIS game object may help learners who would otherwise feel overwhelmed. Data collected from our previous ARIS workshops

includes each step a learner took to create their ARIS game. This step-by-step data could identify successful and unsuccessful computational making patterns to help create digital scaffolding that supports the learner at each development step of ARIS. Combining this support with a storyboarding tool could bridge the gap between non-digital and digital interfaces.

Future research in design scaffolds for computational making should consider both non-digital and digital scaffolding approaches. For instance, we could redesign the digital or the paper storyboarding cards to demonstrate how game objects work together in the editor. This would also reduce issues as learners transition from non-digital to digital.

Combining Puzzle and Narrative Metaphors

To help resolve issues during transitions between non-digital and digital interfaces, we propose prototyping a puzzle approach to the non-digital tool. For example, one of the suggested changes to ARIS storyboarding cards (i.e., Study Two) was to incorporate a puzzle approach similar to the block-based programming method used by visual programming tools like Scratch. A puzzle approach can show learners which ARIS game objects connect prior to using ARIS's digital interface. Historically, ARIS used narrative terminology including game objects such as characters and conversations rather than a puzzle strategy, thereby encouraging a more narrative-based programming approach. ARIS also attempts to display games as a linear story as the learner is building because everyone is familiar with narrative terms and the linearity of a story. ARIS then uses terms for their ARIS game objects such as events, factories, items, and locks, which do not have the same universal meaning as the narrative objects.

Despite their differences, both categories of game objects work together to create ARIS games. A puzzle approach combined with ARIS's narrative metaphor could help meld familiar and unfamiliar terminology and ideas by visualizing how each game object works together to create their story or game.

In addition to implementing a puzzle approach within a narrative metaphor, block-based programming tools could attempt to implement narrative metaphors. For example, block-based programming tools could incorporate narrative terminology that is already familiar to learners. This would create block-based elements that are immediately familiar to learners, and thus, provide immediate understanding about the visual programming tool.

Public Distribution of Storyboarding Tool Changes

Moving beyond the implications this research has for ARIS and the literature of computational making and design scaffolding, we also made contributions through the distribution of a storyboarding course. Working alongside the ARIS designers and the ARIS community has allowed our research to contribute the redesigned storyboarding tool as an ARIS storyboarding course. The course is on the ARIS courses webpage, where anyone can access information on how to use the storyboarding tool, download a list of required materials, and download a printable version of the ARIS storyboarding cards (https://fielddaylab.wisc.edu/courses/storyboarding). The distribution of these changes ensure this research impacts a larger community than those reading this thesis. This may also support my primary goal to help educators support learners engaging with computational making in ARIS.

DELIMITATIONS AND LIMITATIONS

There are both delimitations and limitations to this thesis research. Delimitations are the choices I made as the researcher that should be discussed. Limitations are factors of the research that influenced the results and were outside of my control.

Delimitations include the visual programming tool I chose to use and which learners were interviewed. First, I chose to use the visual programming tool ARIS over other tools (i.e. Scratch, Alice, etc.) because I am familiar with the ARIS tool from previous research experience. Second, I selected six participants (out of 11) to interview from the ARIS workshop. These participants were selected based off their varying computational making processes and expertise with ARIS, which I deemed as representative of the variety that was seen in the workshop.

The limitations of this research include time constraints, a lack of diversity with learners, previous coding expertise learners had, and the fact that the example game was not played outside. First, time was a limitation because I needed to complete this thesis by a specific date. This limitation led to not interviewing all learners because I did not have time to analyze that many interviews. Second, there was a lack of diversity in the ARIS workshop with learners. The workshop was all female, Caucasian participants. Third, because we recruited participants from a local makerspace, several learners had previous coding experience. Three of the learners had previous experience with ARIS. This can make it difficult to make claims about scaffolding novices because of their expertise. Lastly, due to weather constraints, we were unable to play the example game outside, which is how it was intended to play. This affected our results as we saw the majority of learners' games not include location functionality.

CONCLUSION

In this study, I investigated how non-digital design scaffolds in the form of introduction activities and a storyboarding tool could be incorporated into a computational making process. I found that design scaffolds can greatly influence learners' computational making processes by exposing them to the visual programming tool in question before they begin developing their idea and then helping them develop their own idea within the constraints of the visual programming tool. By exploring design scaffolds specifically within the visual programming tool ARIS, I contributed usable insights for researchers and educators who use ARIS for computational making. In addition, by investigating potential design scaffolds such as debugging activities and non-digital tools, I contributed to shifting the current focus in computational making literature from what it does for learners to how we can better develop design scaffolds that will support learners engaging in computational making activities.

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APPENDICES

Appendix A: LEARNER INTERVIEW PROTOCOL

Questions after learners went through ARIS computational making process:

(1) Tell me about the first day of the workshop

    a. What were the challenges?

    b. What was successful?

(2) Tell me about the debugging activity on the first day

    a. What were the challenges?

    b. What was successful?

(3) Tell me about the game you created.

    a. How did you come up with this idea?

    b. What motived you to make a game about this topic/idea/issue? OR what is your personal connection to this topic/idea/issue?

    c. How did your game idea change as you storyboarded?

    d. How did your game idea change as you developed your game in ARIS?

(4) Tell me about your storyboarding process.

    a. What was the hardest part about storyboarding?

    b. What was the easiest part about storyboarding?

(5) Tell me about the process of transitioning from storyboarding to the ARIS editor.

    a. What were some of the successes? challenges?

    b. How did the storyboarding process help you build your game in ARIS?

    c. Potential follow up: Why did you choose not to storyboard?

(6) How did you use your storyboard when you were building your game in ARIS?

(7) What is your favorite part about learning ARIS?

(8) What is your least favorite part of learning ARIS?

(9) [For past ARIS users only] How has your past ARIS experience help you in this workshop so far?

(10) What else would you like to share?

Appendix B: ARIS DESIGNER INTERVIEW PROTOCOL

Questions before discussing the process and tool that was used:

    (1) Where have you observed the biggest challenges in on-ramping learners to the ARIS platform?

    (2) What strategies or methods do you typically use to introduce ARIS to learners?

    (3) How should or could a physical (paper?) storyboarding tool support the ARIS development process?

Questions after discussing the process and tool that was used:

    (1) How did this tool align with your vision of how storyboarding should support the ARIS development processes?

    (2) What were some of the strengths of the tool/process you noted? What were some of the weaknesses?

    (3) How do you think this tool would affect learners' overall design process in ARIS?

    (4) How does this compare to the previous tools or processes you've used to on-ramp learners in ARIS?

    (5) What other tools, approaches, or processes should we consider in introducing ARIS to learners?

    (6) What other thoughts or reactions do you have about the tool/process I presented that you have not yet shared?