Participatory Scaling Through Augmented Reality Learning Through Local Games

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Abstract

The proliferation of broadband mobile devices, which many students bring to school with them as mobile phones, makes the widespread adoption of AR pedagogies a possibility, but pedagogical, distribution, and training models are needed to make this innovation an integrated part of education, This paper employs Social Construction of Technology (SCOT) to argue for a *participatory* model of scaling by key stakeholders groups (students, teachers, researchers, administrators), and demonstrates through various cases how ARIS (arisgames.org) — a free, open-source tool for educators to create and disseminate mobile AR learning experiences — may be such a model.

Keywords: Augmented Reality; participatory scaling; mobile computing; design-based research

The mobile devices we have intimately sheltered in our pockets and bags over the last decade are indicative of the most rapid, broad adoption of communication technology in history (Comer and Wikle 2008; Dikkers, Martin, & Coulter 2012; Horst & Miller 2006). Beyond changing the way we communicate, this mobile revolution has ushered in a wave of new learning tools (Klopfer 2008). With some schools adopting "Bring Your Own Device" policies, mobile devices show learning potential even without overt pedagogical application (Squire & Dikkers 2011); however, new models of pedagogy, distribution, and training are needed to make this innovation an integrated part of learning.

Since 2008, the authors have been involved in developing and refining the Augmented Reality (AR) and Interactive Storytelling (ARIS) platform, a tool that as of September 2013, had been used by 5,402 game designers to create 7,311 games played by 16,744 people in several countries. ARIS started as a pilot project for prototyping AR games on iOS devices and has grown into an architecture used by multiple institutions around the world. ARIS is both an open-source *tool* for creating and disseminating mobile AR learning experiences and a *socio-technical network* of educators who develop and exchange resources and best practices.

Using the case of ARIS, this paper asks,

- How did a modest academic development project become a platform used by thousands?
- How are AR game / learning experiences evolving in response to users' needs?
- What does this case suggest for theories of scaling and educational software development?

Examining multiple generations of ARIS development, we argue for *participatory scaling* as a philosophy for developing and strategy for disseminating educational interventions. This approach builds on Penuel and colleagues (2011) model of *design-based implementation research,* but seeks to explicitly adopt a participatory approach to design that invites users to participate as co-designers. It treats innovation as a series of conversations between educators, designers, parents, researchers, and critically, students (Jenlink & Reigeluth 1996; Squire, MaKinster, Barnett, & Barab 2004). As Fishman and colleagues (Fishman, Marx, Blumenfeld, Krajcik, & Soloway, 2004) point out, participatory approaches to educational change are not without their flaws, particularly because they place extra burden on already overworked teachers. Yet, ARIS has thrived in such a context, and this case study seeks to better understand why, while also reporting relevant lessons toward the immediate future of mobile AR app development in education.

Theory: Place and Learning

Over the past decade, our work on mobile media in education has gravitated further and further toward place-based pedagogies (Dikkers, Martin, Coulter, 2012; Gruenewald, 2003; Squire, Jan, Mathews, Wagler, Martin, DeVane, & Holden, 2007). Our interest in place-based pedagogy arises at the intersection of situated learning theory, critical pedagogy, environmental education, and game-based pedagogy (Klopfer & Squire, 2008). Situated learning theorists, most notably James Paul Gee (2003), argue for digital games and simulations as a promising model for instantiating situated learning theory. In short, games immerse learners in complex situations where knowledge is used to solve problems. AR for learning is particularly promising as it enables designers to organize learning around real world issues. Places hold meaningful embodied stories, and AR technologies provide a vehicle for making these stories accessible to learners.

Rooted in place-based pedagogy, this approach argues that learning can be profound when rooted in *place* (Gruenewald, 2003). Specifically, learning embedded in the particular histories, environment, and culture of place (ideally students' lifeworlds) can: (1) make learning relevant; (2) demonstrate the power that knowledge can have in understanding the world; (3) promote agency among learners; (4) raise equity and issues within the curriculum; and (5) address pressing global environmental concerns. As such, place-based educators pursue radical localized curricula where all learning emanates from understanding local places — most often school grounds, neighborhoods, watersheds, communities and local municipalities. Gruenewald argues that critical place-based learning offers a particularly powerful way to instantiate critical pedagogy because it starts from students' experience and place and draws learners toward naturally interrogating their place in society.

AR and Place-Based Learning

By allowing mapping of digital content onto physical places, AR can support the reading and writing of stories connected to physical place. Learners can map stories and learning experiences on to physical places, and use AR platforms to share stories about their work. This sort of learning interaction, amplified by mobile devices, provides the potential for innovative learning. Past work with AR games has demonstrated their potential for situated learning, engaging disaffected learners, supporting inquiry, and fostering scientific argumentation (Jan, 2010; Klopfer, 2008; Squire & Klopfer, 2011).

However, to date, AR projects have been "boutique implementations" supported by extra researchers and staff that have struggled to persist beyond researcher involvement. A lack of available hardware and school policies that prevent students from leaving campus, or dissuade Internet use in class are just two obstacles facing AR. How do we localize content for teachers and students? How do we support educators and learners in becoming authors of their own content? How do we build and maintain momentum among key stakeholder groups?

Participatory Design-Based Research

We have been using *participatory design-based research* methods to iteratively develop technologies, pedagogies, and user communities. We describe our approach as participatory in order to capture how users participate as designers of ARIS. We adopted this approach so as to engage key stakeholder groups as early adopters who can help identify new features, user test existing features, and shape the direction of the project. We wanted to work closely with educators to build features that *they* valued, in addition to those that we anticipated being useful.

Through the following case studies, we describe how ARIS was iteratively built through an initial prototype and fleshed out through successive iterative cycles. This participatory approach builds on existing design-based research models (particularly Collins, 1992) while also integrating ideas from lean software development, such as designing for community and minimal viable product design (Kim, 2000; Ries, 2009). Specifically, it seeks to understand what features users want in emerging technologies so that they can be shaped by users themselves, through iterative cycles of design, research, refinement, and deployment (see Dikkers & Squire, 2011, Pinch & Bijker, 1984). This model of participatory design research might be most useful for those interested in emerging hardware platforms (Murray & Olcese, 2011). We close with a discussion of implications of this work for supporting critical, place-based learning using technologies (Gruenewald, 2003).

Minimal Viable Products and Participatory Scaling

The ARIS platform, which enables easy creation of AR learning activities, is open-ended, and relatively accessible, as evidenced by the thousands of users who have created games with it. Unlike many academically-derived projects, ARIS has been developed with relatively little grant money. Rather, it has been bootstrapped by partners interested in adapting it for their context. Thus, it has grown organically as users

have expressed interest in using it, and it has grown in directions that different organizations want to take it.

This approach, shares many features with building Minimal Viable Products (MVP). MVP, essentially, is a process by which developers "release early and release often." Ries (2009) describes two problems facing contemporary software development: (1) Developers do not receive feedback from users until the end of development, at which point it may be too late to change direction in project, and (2) Developers frequently "run around in circles, chasing what customers think they want." MVP advocates releasing good products with minimal feature sets to get feedback on what customers want (and do not want) to assist with prioritizing development. Ries advocates releasing products with minimum features and working closely with "earlyvangelists" (visionary early adopters) to avoid building products that no one wants and to make more efficient use of resource dollars, focusing on critical, needed features first. The goal of MVP is to learn about customers' needs as quickly as possible through building products and features that they need.

ARIS: Humble Beginnings

Similar to the MIT AR engine (Environmental Detectives/Outdoor AR), ARIS began as a class project (Gagnon, 2010) to create a prototyping tool for game-based learning. The core concept of ARIS is to allow players — using GPS and QR Codes — to immediately experience a hybrid world of virtual interactive characters, items, and media placed in physical space. A few months later, Squire (2009) was awarded a grant from the MacArthur Foundation for studying youth mobile media use that included a small budget for prototyping mobile learning experiences. This helped evolve the authoring tool from a PHP table-driven environment to a simple browser-based drag-and-drop environment.

A unique partnership quickly formed with University Academic Technology, who began supporting ARIS as a university project and product. University Academic Technology saw an opportunity to build tools and resources for university classes, and draw from School of Education expertise. For faculty, a partnership with Academic Technology meant: (1) Resources for developing research tools; (2) Methods for reaching new research participants through University courses; (3) Ways to make a local impact on campus; and (4) A path toward sustaining the project beyond any one grant.

Core User Groups

The majority of ARIS designers are introduced to ARIS through playing a game made with ARIS or attending a presentation (either live or virtually). Then, designers use ARIS in one of three contexts: (1) independent exploration, (2) participation in an organized workshop or design jam, or (3) collaborating directly with the ARIS development team to design an instantiation. These formal collaborations, usually funded with grants or contracts, have sustained ARIS development.

As an open-ended and accessible tool that supports users in sharing stories, ARIS has spread well beyond its originators. Perhaps most importantly, it has inspired users, particularly instructors who may not be interested in technology, to experiment with new pedagogical practices and bring their own ideas about how place and curriculum can interact. Newcomers use others' worked examples as models to build their own ideas into implementations in their local geographies. These backyard experiments, sometimes in rather large backyards, in turn inform the ARIS team in design, development, and academic understanding of AR's educational impact.

Additionally, a simple community-based support system (Google Group) connects ideas and users, who are commonly invested in designing hyperlocal learning experiences, while contributing towards the development of a global platform. Educators number significantly among the 5000+ authors, and represent informal education institutions such as parks, museums, and afterschool programs, as well as formal ones such as K-12 and university instructors and students.

Example Projects and Partnerships

The three projects illustrated below represent participant designs and provide a glimpse of some pedagogical visions surrounding AR-fueled place-based learning. These examples show how partnership with outside groups funded both ARIS platform maintenance and new ARIS features that can be used by others — features asked for by the users based on ongoing design. For example, projects such as "Then, Now, Wow" and "Mobile Quest" (described below) can quickly change terms of participation around a given tool, taking one geared towards prototype production and using it instead to scaffold student design learning. Early adopters, such as Holden and Sykes (2011) can put a tool to real use before it is ready for the general public, push boundar-

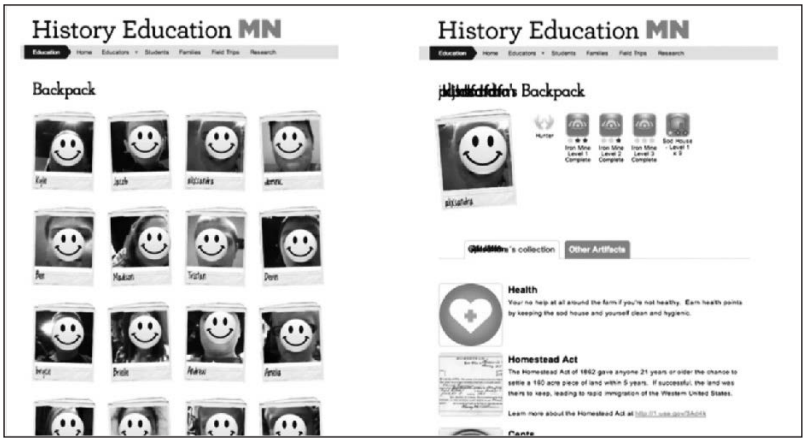

Figure 1: Example digital backpacks for the "Then, Now, Wow" Exhibit

ies of what may be possible, and produce second order effects of popularizing and promoting AR design and use by finding and helping others experiment with it. We also consider a case at the university level, called "Folklore", to get a closer look at how interactions between researchers, teachers, and students produce knowledge that takes form, in part, in further development of AR-related pedagogy, and become instances to which educators worldwide can refer when establishing their own programs.

Then, Now, Wow

One example of a large scale project informing overall development is Minnesota History Center's "Then, Now, Wow" exhibit, funded by a $2.5m Legacy grant to produce field trip experiences that connect to classroom history curriculum. They wondered how AR might interact with the physical environment as a new tool for interpreting history. This prototype has been used in dozens of user tests, with over 1000 youth. The platform needed to be reliable and robust at a level beyond simple classroom or prototyping. The server alone had to scale to hundreds or thousands of users at a single moment. APIs were created to integrate with enterprise computer systems and allowed custom reports and visualizations of player performance. For example, the digital backpack allows teachers to visualize individual in-game experiences of their students. These custom features designed specifically for "Then, Now, Wow" are being generalized and folded back into ARIS so all can benefit from them. Effectively, the Minnesota Historical Society is underwriting platform stability and the means to extend ARIS far beyond their use.

Mobile Quest

Funded through research grants from the Pearson foundation and New Learning Institute, the Institute of Play has been conducting week-long summer camps for youth in New York and Chicago. These camps were originally used to orientate incoming students to the Quest2Learn schools but have now developed their own autonomous curricular goals — to teach digital literacy, creative problem solving and collaboration while practicing design thinking for AR. This effort defined a strong new use case that others have since followed. A number of features were added to support the first Mobile Quest camp in 2010, most notably the ability of authors to copy their games and include other users as co-authors. Though these features make sense generally, and indeed have been popular, they were developed because teachers at Mobile Quest needed them as a basic ingredient to address their curricular goals.

Folklore

In the fall of 2012, the Engage program at UW–Madison assisted three instructors in creating and implementing mobile-based Situated Learning activities for their courses (Engage, 2012). In Folklore, an activity was designed where students self-organized into groups of five and were given one iPad (with an unlimited data plan) per group. The instructor assigned his 80 students to map and document (with photographs, video, and text notes) places on campus that they felt embodied their own university experience, share with the class, then visit their peers' notes in the context of their significant places. In the first two weeks, they had an overview of course themes, and were tasked with identifying those themes depicted on campus in a *place*, a piece of *folk art*, and two *stories* (interviews) of a significant campus event for a student. They were given two-and-a-half weeks to document and geotag these things, and to tag them with: 1) the folklore theme they address; 2) their class rank (freshman, sophomore, etc.); and 3) their username. They also were asked to comment on two others' notes, and to visit the location of at least one peer's note. Analyzed data includes student in-game notes and comments, post-activity reflective essays, and instructor interview. Themes were collated and validated using intercoder reliability (Kurasaki 2000).

Design features needed to deliver this classroom AR experience included the ability to document locations with photos, video, and a notetaking feature that would also be geotagged. Editor development followed the instructor demands for the features in order fill in a players' ability to create or represent understanding within an AR experience. Notably, the instructor's interest in the activity was not what students could design, but what they could add to a set of instructor prescribed lenses to see the world.

As a server-based GPS game, every movement and decision by players are logged. To scale and share individual experiences to class experiences, ARIS maps out notes in the Web Notebook, where they are grouped and displayed according to tags or contributors. The web notebook allowed for reflection on notes after the three-week activity. Nearby notes are clustered, and when clicked, the map zooms to clustered notes.

In addition, this instructor captured user feedback from the AR experience providing insights on how students perceived AR technology and potential benefits to their own learning. Users identified key assets to the AR technology as amplifying their engagement with the course content, increasing understanding of course concepts, improving collaboration, and community building.

Engagement. Students found the assignment engaging because it forced them to think about and identify course concepts that were visible in familiar places — their own campus and daily lives.

> **Student**: "The ARIS project was one of the most engaging projects I have taken on so far in college. It managed to keep me interested by providing a set of guidelines that had to be followed while still keeping it open enough to include what interests you."

They benefited from sharing what they noticed with their peers, and from seeing and commenting on what their classmates had geotagged. The sharing resulted in their seeing more examples of course content tied concretely to places on campus that they encounter daily.

> **Student**: "Freshmen tend to choose residence halls or places of academics or business. Upperclassmen tend to choose places that are not associated with the University such as a public park maybe. I think this is because the older you get, the more likely you are to live off campus."

All was not perfect though: Students and instructors/TAs reported a great deal of frustration with the technical aspects of the assignment — specifically, in uploading large videos via the cellular data system.

> **Student**: "We sometimes struggled to get things posted to the game seemingly from glitches, and sometimes struggled to access the game itself, but considering this was the first run through with students, on the whole it went quite smoothly."

Course Concepts. The instructor and Teaching Assistants confirmed that student field notes demonstrated a good understanding of course concepts and themes, effectively applied. In their reflective essays, students further demonstrated expanded understanding of course concepts gained from peers' notes.

> **Student:** "The group who interviewed the State Street drummer expected to hear about why he drums on the street, but instead received a history lesson about the Uribai people. A large part of folklore is communication and interpretation. When the interviewer asked the man about himself, he may have interpreted that to mean they were asking about him and his people. It seems that he strongly values his cultural background and that his identity spreads much further than himself as an individual."

The sharing of examples also allowed students to aggregate recurring themes.

> **Student:** "One of the biggest recurring themes I found when going through the notes from the other teams in the game was the self-representation of student life. Not only how students represent themselves

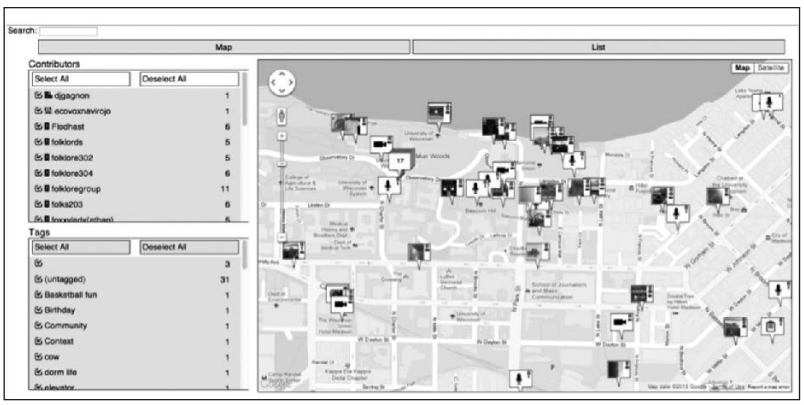

Figure 2: Mapped Notes in the ARIS Web Notebook

Figure 3: Notes can be clicked on and viewed so students can revisit their own and others' notes for reflection

here on campus by what they do, how they act and things like that, but also what that says about the students and how it exemplifies certain values that we are proud to hold ourselves to here on campus."

Collaboration and Community Building

Beyond course concepts, the instructor and students felt class collaboration and community were enhanced. In the notes, this was evidenced by comments students left each other (image above). The instructor also reported an increase in class community, which he attributed to the mobile situated learning activity*:*

> **Instructor:** "Students were forced to engage in collaborative problem solving from the start of the course. I noticed after the game was done, students were less likely to see themselves as individuals in a classroom, and more as a community of students with the common aims of learning together and from each other"

Conclusion and Significance

These worked examples and their initial evaluation suggest that situating learning activities in authentic contexts can enable a number of powerful pedagogical triggers. In one sense, they are derived from of course decades of theory and practice about situated learning and more narrowly the earlier AR experiments in Wisconsin, Boston, and Albuquerque. But they are not repetitions of a set AR curriculum or model. They avail themselves of that shared history of practice, new tools that are significant iterations on those used previously, and represent steps into new curricular areas, arrangements, and goals. We look at these cases, not so much with an eye to seeing them closely replicated, but for the impact they will have on the community and how they influence the directions of new experiments that may only be distantly related.

Along these lines, we do notice some common features. Teachers perceive improved engagement with mobile experiences, but also are inspired to pass along the tools of creation to their students. Empowering student learning through design serves to meet teacher curricular and educational goals within the subject areas and including life skills like problem solving, collaboration, critical thinking, and citizenship. Because mobile experiences are localized, they lend themselves to authentic local engagement and provide a classroom voice within their community. These examples resonate with educator-focused case studies of teachers using locative games (Dikkers, Martin, Coulter, 2012) where authentic contexts provide pedagogical opportunities for teaching and learning.

Students feel personally connected to the content, perhaps because they are engaging a greater number of their physical senses through interaction with the content/activity. Instructors report that the students feel more socially connected to others in the class more quickly than typical, perhaps because of the small-group collaborations, and peer-to-peer sharing and commenting. Students perceive that these activities increase their learning, possibly due to the immersive nature of the activity. Another possibility is the agency that design allows the learner in creating content that is relevant to their communities. Initial studies of student use of mobile devices show that even without programmed material, the mobile devices themselves can be "amplifiers" of learning activities (Squire & Dikkers, 2012). We suggest that with programmed augmenting of reality this effect can be even more pronounced and focused. However much more would need to be researched to make claims or measures of learning in such settings.

Limits to use by teachers and students include the availability of devices, internet connections, and the comfort level of the educator with locative learning. However practitioners found these challenges to be worth overcoming for locative learning opportunities provided by mobile media learning. Interestingly these challenges did not include student time-on-task, behavior concerns, or misgivings about digital access by learners. Instructors generally saw these challenges as natively addressed by the pedagogical approach or, at least, it is possible that the novelty of the activity delayed these management concerns.

Mobile devices are nearly ubiquitous in the American higher education system, where they enable a tremendous level of peer-to-peer interaction and just-in-time learning at an informal level. Traditional academic practice has not evolved accordingly. These cases suggest that there are areas of integration that can be developed more tightly, intentionally, and with potential effect that teachers desire in innovative pedagogical design. Furthermore, their place within an evolving participatory structure suggests that we should be concerned with more than their immediate efficacy.

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