Traversing Transmedia Together: Co-designing an Educational Alternate Reality Game For Teens, With Teens

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ABSTRACT

An Alternate Reality Game (ARG) is an interactive story-game hybrid whose core mechanics include collaborative problem solving and storytelling. ARGs are also participatory experiences, because game designers dynamically adjust content in response to players' actions as game play progresses. What if the participatory process was extended during the design phase of an ARG as well? Few, if any, studies have explored how to include player populations in the ARG design process – especially ARGs that target youth. In this paper, we share the process we followed to design a large-scale ARG to promote scientific inquiry *for* teenagers (13-17 years old) by partnering *with* them. Our findings suggest that co-designing with youth resulted in novel design features in the final game, and gave us insight into adolescent attitudes toward various scientific concepts. We also share co-design techniques that were not as effective and offer suggestions for future approaches.

Author Keywords

Alternate reality games, teens, adolescents, co-design, participatory design, learning, transmedia storytelling.

ACM Classification Keywords

K.3 [Computers and Education]: General.

INTRODUCTION

Increasingly, games have been studied as platforms for engaging players in pro-social causes [55,75] and inquiry-based learning [71,73]. In particular, Alternate Reality Games (ARGs) hold potential to promote meaningful learning experiences, because they extend the boundaries of traditional game spaces into everyday life using commonly available media, and because players inhabit ARGs as themselves, not as digitally rendered avatars [8,38,46]. The literacy and inquiry skills needed to tackle an ARG, such as transmedia navigation, information evaluation, and collaborative problem solving, include the same set of skills needed to solve many real-world issues [45,55]. Consequently, ARGs have garnered increasing attention as potentially transformative vehicles for learning [15,23,59].

Despite the recognized potential of ARGs as novel tools for informal learning, few large-scale ARGs have been developed or evaluated that focus on learning in Science, Technology, Engineering, and Mathematics (STEM) domains. A handful of ARGs have been developed with learning goals in mind, such as *World Without Oil* (WWO) [24,44,55], in which adult players imagined their lives caught in the midst of a global oil crisis, and *Black Cloud*, in which high school students investigated climate change issues in their neighborhoods [59]. Whether the ARGs were created for entertainment or education, most current research focuses on game play and player participation [18,44,53], not design. Few studies have explored the process of designing education-based ARGs for teens (13-17 years old) by involving teens directly in the process.

The study presented in this paper is part of a larger, multi-year, design-based research initiative to explore design strategies for developing ARGs for informal STEM learning. The focus in this paper is on the approach we took *to include youth in the design process*. Our target audience is teenagers, 13-15 years old, who are currently underrepresented in STEM, including females, blacks, and Hispanics [57,58]. A key issue we investigated is how co-designing with teenagers might enhance game design and game play for teens. We also sought to collaborate with teens on designs that integrate scientific inquiry as naturally as possible into gameplay [35]. Research questions that arise from these issues include:

- ***RQ#1****: What techniques lead to constructive design insights when co-designing informal STEM learning ARGs with teens?*
- ***RQ#2****: What co-design techniques give us insight into teens' knowledge, abilities, and attitudes about STEM?*

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In this paper, we share our 10-month co-design process, exploring techniques that we found were effective (or not) with teen co-designers, and psychographic insights we gained into our teen co-designers' perspectives on STEM.

BACKGROUND

This section situates our study in the broader participatory design and learning sciences' landscape, and forms the basis for our efforts to understand how learning experiences such as ARGs can be designed in partnership with teens.

Co-Design and Youth

Participatory Design is an array of theories and research methods whose core philosophy is to include end-users as active participants in the technology design process [56, 69]. While participatory design's original focus was on trade union laborers (adults) in the workplace [5], it has been extended over the past 40 years to include many other user populations across multiple contexts, such as individuals with disabilities [32], older adults [26], and communities engaged in urban planning and policy [33]. Cooperative Inquiry is just one of many participatory design methods, one that focuses on involving youth in the technology design process (7-17 years old) [21,22].

Children (7-17 years old) can assume various roles throughout the technology design process [22]. For example, researchers can observe a child field-testing a completed prototype as an end-user, or they can collaborate more directly with children who act as informants while crafting system prototypes [17,54]. In Cooperative Inquiry, children act as full partners with adults throughout the design process, sharing ideas and evaluations equally with adults [22]. Adults also play active roles throughout the process by helping youth designers articulate and synthesize their ideas [35,84]. Because of the emphasis Cooperative Inquiry places on equal partnership between children and adults, it is often referred to as *co-design*.

While Cooperative Inquiry has been used successfully with children, 7-11 years old [19,25,35] for almost two decades, co-design with teenagers (13-17 years old) remains a less explored research area [66]. One challenge of co-designing with teens is logistical: teenagers are often busy with extracurricular activities such as sports, after-school clubs, or part-time jobs and cannot devote the time required [67,86]. Other challenges are related to adolescence as a stage in human psychosocial development. For example, teens may not actively participate in design research because they do not feel capable of providing adequate data to researchers, are uncomfortable about the research environment, or are concerned with appearing "different" [41,42,65]. Many existing design studies with adolescents use more traditional research methods (e.g., ethnographic studies using participant observation and interviews), or they engage teens in limited design roles, as end-users or informants in focus groups [29,65]. However, because teens represent a rapidly growing group of technology users [51], researchers have sought new ways to involve them more fully in the design process [30,67,77,82]. Still, many questions remain about how to develop effective co-design techniques and partnerships with teens [66]. A few of these questions include: Can co-design techniques used with younger children be used effectively with teens? If so, which ones? If not, how might existing techniques be modified [86], or new ones developed [42]? In this paper, we explore responses to such questions, with a focus on co-designing interactive narrative experiences like ARGs.

Co-design, ARGs, and Participatory Learning

In addition to increasing opportunities for teens to be co-designers of their own technologies in general, there is growing interest in involving youth in design research to create new, participatory learning experiences [7,17,19,42]. Increasingly, education researchers and HCI designers are co-designing with children and teens to meaningfully map their technology use to its potential to support personally relevant and socially situated learning (e.g., 14). Ahn et al. [1,3] conducted two years of iterative co-design sessions with youth (12-14 years old) to explore the design of social media platforms that support STEM learning. Similarly, Bonsignore et al. [11] engaged in a year-long co-design effort with children (4-11 years old) to develop a mobile storytelling app that has a worldwide user base of over one million educators and families; most of whom use the app to promote literacy learning. Designing with youth can also enhance our understanding of the conceptual processes of the learners themselves [3,7], and have shown potential to benefit the learners who participate in their design [36,54]. Likewise, Yip et al. [85] highlighted ways in which content expertise and design expertise affect children's co-design processes and related design ideas. Overall, several studies have demonstrated the value of co-designing learning technologies with youth (7-16 years old) [3,17,42,71].

Research in game-based learning [75], game design [69], and e-textiles [28,47] has also demonstrated that children can develop problem-solving expertise and increased agency from their active participation in "design thinking." Just as design thinking is an integral element of these approaches, design thinking is promoted in co-design. Our study integrates co-design techniques with research on design thinking in games not only to examine how different co-design techniques may enhance player interaction in ARGs, but also to gain deeper insights into teen dispositions and motivation toward STEM concepts.

METHODOLOGY

The co-design process and techniques that we used in this study are part of a multi-year research project to explore the potential of ARGs as transformative tools for informal STEM learning with a target audience of teenagers (13-17 years old). We used a case study design to examine our co-design process [49,83]. Our case study includes three groups of teen co-designers who worked with our team from January-April 2014, and a larger population of teens who participated as playtesters in October 2014.

Design Context and Co-Design Partners

Our informal learning ARG, called *DUST* (fallingdust.com), targeted a diverse teenage demographic and was designed to foster scientific inquiry skills. *DUST's* narrative focused on a group of teens who witnessed the worldwide collapse of adults in the wake of a historic meteor shower. Faced with a potentially apocalyptic scenario and their own impending collapse, the teen characters turned to our players for help in solving a series of problems in order to revive the adults and uncover the mysteries of the meteorite dust that had fallen from the sky. *DUST's* learning goals were to help players develop scientific inquiry skills, such as forming and testing hypotheses, and collecting and analyzing data.

DUST's design and research team included a diverse group of game designers, creative writers, artists, musicians, researchers, programmers, scientists, and content experts from a variety of institutions including Brigham Young University (BYU), the University of Maryland (UMD), NASA, and Tinder Transmedia, a transmedia production company. Our team of co-designers included middle school and high school students (13-17 years old) from across the United States (US). Following the Cooperative Inquiry philosophy of including youth throughout the design process, from ideation to completion, we conducted several phases of co-design to develop *DUST*.

Early Co-design and Ideation Phase (Jan-Apr 2014)

At the outset of our design process (January 2014), we held an introductory co-design session with key members of the ARG research team and a small group of teens (2 girls, 2 boys, 13-15 years old). Our goal was to familiarize everyone with Cooperative Inquiry and co-design techniques more generally. This session was important for adults on the design team who were unfamiliar with co-design's democratic philosophy and suite of techniques.

The narrative design and player activity ideation phase began in mid-February 2014, during which we co-designed with 40 teens (13-15 years old) in three different after-school groups. We recruited teens from two different metropolitan regions in the US: 12 teens participated through an existing after-school program [1] in Washington, DC, while 28 participated with recruitment help from a local science teacher in Provo, Utah. The DC teens came from two middle schools in a large, urban school district where 88-99% of students represent minority groups (depending on the school) and nearly 77% qualify for free and reduced meal programs (predominant minority is African-American). Three adult members of the design team had worked with the DC teens for two years in an after-school program that promoted STEM learning through science fiction storytelling [2], and included co-design sessions throughout the program [3]. As a result, the DC teens had developed a robust, collaborative relationship characteristic of the full co-design partner roles that youth and adults assume in Cooperative Inquiry [22,27]. The Provo teens came from a large suburban school district where over 35% of students represent minority groups of non-native English speakers (Hispanic). Initially, the Provo team was less familiar with co-design techniques and power dynamics (equal partnership between adults and children). However, by the end of two months of weekly design sessions together, the Provo teens appeared comfortable partnering with adults and many volunteered as playtesters during the final DUST design phase. We developed seven co-design sessions for these three groups that focused on character design, user interface design, and familiarizing young teens with ARGs as a genre (Table 1). At each session, five to seven adult co-designers (professors, graduate, and undergraduate students) partnered with the teen co-designers and reflected on the utility of the techniques via post-session debriefs and field notes. All told, we held 21 sessions over eight weeks with 40 teens.

We modeled our teen co-design sessions after the traditional Cooperative Inquiry format [21,27], which segments a design session into several distinct components. *Each component of a Cooperative Inquiry design session acts as a building block that steps toward a comprehensive view of a design problem and its potential solutions in the same way that methods' triangulation in qualitative data analysis* [62] *offers multi-faceted views into research data*. At the start of a session, all co-design partners share a snack together. This helps transition adults and youth from a power dynamic of "You are Kids and We are Adults" into a more balanced mindset of equal partnership in a design task [27,37]. Snack-time also attunes adult researchers to specific, day-to-day issues that youth co-designers may be experiencing that can affect their attention levels or enthusiasm in a design task (e.g., stress over school). After snack-time, all co-designers (regardless of age) respond in-turn to a design "Question-of-the-Day" (QoD). The purpose of the QoD is two-fold. First, the QoD serves as a warm-up and bridge between co-designers' everyday lives and technologies and the session's main design challenge. If the design goal, for instance, is to generate ideas for a new social media-sharing app, the QoD might be "What was the last thing you shared, and how did you share it?" Second, the QoD allows researchers to informally collect data on the co-designers' existing perspectives on topics related to the main design challenge, like perspectives on what the word "science" means, or who can be a "scientist" (key ideas related to the hoped for learning outcomes of our ARG).

After a brief whole group QoD discussion, the main design challenge is issued. A design challenge might be: "Design an app to share science questions and investigations with friends." During this part of the session, the whole group typically divides into teams of 3-6 (balanced with 1-2 adults working with 2-4 youth per team). Teams collaborate on the design challenge for 10-20 minutes (depending on time constraints), after which everyone regroups to share their design ideas. One to two members record the ideas and conduct an initial round of frequency analysis and open

Co-design session summary (includes individual session Goals, Design Techniques, and Descriptions)
1) Preliminaries. *Goal*: To introduce ARG research team & "test teen" group to the co-design process (4 teens, 13-15 years old). *Techniques*: Sticky notes, Bags-of-stuff [27,80]. *Approach*: Teens and adults shared their favorite fictional characters and/or celebrities to gain insights into character traits and narrative touchstones for teens. Transmedia producers outlined the ARG's initial narrative frame and asked co-designers to elaborate on "what happens next?" The Bags-of-Stuff [80] technique involves the use of arts-and-crafts materials to design low-tech prototypes in response to a design prompt, such as "what tools would teens in *DUST* use to solve the mystery?" Sticky notes [27] involves the use of Post-it® notes to brainstorm responses to design prompts (typically when evaluating features of an HCI system/technology), then clustering the responses into themes (i.e., initial frequency analysis of design features).
2) Introduction to ARGs. *Goal*: To introduce DC and Provo teen co-designers to unique features of ARGs (40 teens, 13-15 years old). *Techniques*: Focus group discussion [65] and game-play. *Approach*: Teens and adults played a mini-ARG together and gave feedback on what they liked, didn't like, and other types of interaction or design features they would add.
3) Narrative session. *Goal*: To explore options for extending the ARG narrative beyond the initial story beat (DC & Provo teams). *Technique*: Storytelling Group, in which co-designers respond to "What if?" scenarios with their own stories and perspectives, typically focused on a specific technology system or feature [48]. *Approach*: Professional transmedia writers/producers presented first story beat and design challenge to the co-designers, who formed small teams to brainstorm and map out "*What Happens Next*" in the narrative.
4-5) Character Design sessions. *Goal*: To design in-game characters who share the story and interact with players (DC & Provo teams). *Techniques*: Character Questionnaire [13] and video-recorded Peer interviews [65]. *Approach*: The transmedia writer/producers on the team gave feedback on the co-designers' narrative ideas and issued a design challenge, asking teens to design characters that they'd like to interact with in the ARG. Teens worked in small groups of 2-3 and interviewed each other using character questionnaires [13].
6-7) **Interactive Tools and Activities sessions**. *Goal*: To brainstorm activities that players and characters would engage in to investigate the adults' collapse, and to design tools that would help players conduct these activities (DC & Provo teams). *Technique*: Storyboarding [56,80]. *Approach*: After feedback from the transmedia producers on the teens' character designs, the team's UI Design Lead issued a new design challenge: design STEM-focused activities and tools that players (and in-game characters) can use to investigate the mystery of the meteor dust and adults' collapse (e.g., interactive microscope, brain scanner, interactive telescope, etc.).
8) **Player Community site design session**. *Goal*: To design interactive elements and layout for the community site where players would share data and discuss their progress to investigate the adults' collapse and revive them (DC & Provo teams). *Technique*: Layered Elaboration [79]. *Approach*: Small teams of co-designers reviewed print wireframes of sections of the player community site (e.g., player profile pages), using *transparent overlays* to add their own sketches and annotations. Design reviews of each wireframe were conducted in rounds (about 10 minutes each). At the end of each round, teams shared their ideas to the larger group, added a new transparent overlay to the print wireframe, and passed it on for review by another team. After all wireframes received at least 2-3 rounds of design critiques, common themes and/or unique features were compiled and shared with the larger group.

Table 1: Summary of Co-design Sessions with teens (13-15 years old, Jan - April 2014

coding to develop common themes. An adult usually leads, but children have also led this process [84]. The resultant themes, called "Big Ideas," are used to drive future sessions or prototype development. Timewise, most segments are arranged so that a co-design session can be completed in 90 minutes. Points at which we reshaped or tailored this session structure for teens are detailed in our **Findings**.

Playtesting phase (Oct 2014)

The goal of our second phase of co-design, playtesting, was to get feedback on the entire experience, including the narrative, collaboration platform, apps, learning, and overall gameplay. To introduce the prototype, we held face-to-face introductory playtest sessions with 136 teens (12-15 years old), who interacted with *DUST* online for approximately three weeks. Playtesters could also recruit others to join them in this initial phase. In all, 225 teens (11-17 years old) participated. Playtesters were located across the country, with youth from five states participating. While the DC and Provo teens acted as full design partners during *DUST*'s ideation and early design phase, our playtesters assumed roles more aligned with the informant role [22,71].

Data Collection

Data collected throughout our co-design process included session field notes, video recordings, artifacts produced by our teen co-design partners, and design documents developed by our research team. We recorded, shared and stored all documents related to design sessions in a shared repository with links to field notes to facilitate post-session reflection and analysis. Playtest data was collected using digital traces of player interaction on a beta version of our game website, and notes from face-to-face sessions with teens interacting with the game website and mobile apps.

Data Analysis

Throughout our analysis process, we conducted detailed reviews of our design case, participants, and context, using

"categorical aggregation to establish themes and patterns" [16:156]. We followed an iterative process of first summarizing sessions during weekly design team meetings, with several adult co-designers then reviewing and annotating field notes after each session and throughout each phase of co-design. During our 8-week ideation phase, lead co-design facilitators reviewed individual and team field notes, and focused analysis on our two research questions: 1) what worked (or didn't) with the co-design techniques/prompts used in each session, and options for adjustment in follow-on sessions; and 2) insights into teen attitudes about and interactions with the scientific inquiry topics and activities that they were helping to design. During playtesting, we selected moments that highlighted: 1) teen responses to designs we had integrated into the narrative, and 2) teen interactions with the science topics and activities that the game presented. Once we had completed our two phase co-design process, we reviewed the memos and themes we had progressively developed by comparing themes across sessions within each co-design group, and then across both co-design groups [6,16]. Our final themes emerged from this iterative process of focused coding and comparing across multiple levels of data [6,40].

FINDINGS

In this section we detail our co-design/playtesting process.

Introduction to Co-design and ARGs

At the beginning of our design process, we conducted a co-design session with the research team and four teens to introduce the philosophy of Cooperative Inquiry and a few foundational co-design techniques to those who had never participated in intergenerational co-design ("Preliminaries," Table 1). Researchers and designers new to co-design often carry misconceptions with them (e.g., adults cannot add ideas, or need to teach children first), so participating in a complete, intergenerational co-design session is key [37].

What we learned about techniques. Our teen co-designers responded readily to brainstorming with sticky notes. For the Bags-of-Stuff technique (Table 1), however, we found that the teens preferred to share their ideas in a focus group and interview format, rather than devising low-tech prototypes with arts-and-crafts materials. In prior research, low-tech prototyping with Bags-of-Stuff has had mixed results with teens [10,82,86]. We build upon these studies by noting that when the teens followed a *peer interview*-like process, the volume of ideas they generated increased dramatically (two low-tech prototypes with Bags-of-Stuff versus 30-40 ideas with peer interviews). One reason why Bags-of-Stuff may not have worked as well with teens as it does with younger children may be developmental. Prior research has shown that teens may have trouble with open-ended, hypothetical or "blue-sky" situations, as they are still learning to build their own opinions distinct from others [65,77]. Interestingly, our teens' preference for discussion and interview Q&A contrasts with the difficulties Isomursu et al. [41,42] faced when they interviewed girls (10-16 years old) for mobile app design ideas. We may have had more success due to our Cooperative Inquiry co-design session format. First, we introduced co-design by inviting all participants to engage in an interactive activity that promoted collaborative problem solving and emphasized equal design partnering between teens and adults. We then held our typical round-robin QoD with everyone sitting on the floor, to physically re-emphasize a balanced power dynamic among co-designers, regardless of age. During our design activities (Table 1), all teams worked in a large space on the floor. The arrangement of co-design space is an important consideration to mitigate power structure concerns [20,22], and our format and approach to co-design sessions was quite different from Isomursu et al. [42].

Co-designing Narrative and Characters

An interactive narrative is central to an ARG, and we invited our teen co-designers to orchestrate a storyline that would be engaging and informative for their peers, with characters who could support their efforts to acquire and practice scientific inquiry skills. We explored various techniques to support their narrative/character design efforts, such as "professional" design challenges and video sharing. We also modified the Question-of-the-Day (QoD) as an opportunity to assess teen views of the science content that we were charging them to integrate into the experience.

Embedding science-related content and assessment into QoD discussions and design prompts helped us to uncover teen attitudes and awareness of science topics. Our science-oriented QoDs were inspired by the US National Research Council's goals that today's youth should see science as relevant to their everyday lives, and can engage in public discussions about science with friends and family [63]. In addition to questions related to scientific inquiry, we devised questions that probed our co-designers' interest in science [52,63], and informally assessed their content knowledge. For example, extremophiles (creatures that survive in extreme environments) play a key role in *DUST's* storyline, so for one QoD, we showed our teen co-designers an image of a tardigrade (a type of extremophile) and asked them about its features (what is it? how big is it? what does it eat? etc.). The teens demonstrated that they were comfortable with the concept of scale (most realized the tardigrade was microscopic and the image was "zoomed in," as one teen said). The teens also engaged in scientific argumentation, using evidence to support their ideas. For instance, one teen told us its "legs" are formed so that it can live in water, and another surmised that because it can live in extreme conditions, it could help humans understand how to survive on other planets (or whether aliens exist). Their desire to name the tardigrades after celebrities, like "Rick Ross" (a well-known rapper), or to sell them as pets underscored their playful, random humor, a design issue that cropped up repeatedly during design sessions [4].

In addition to focusing on scientific inquiry and content, we changed the standard co-design QoD from just one question that participants answer individually in a round-robin format. Instead, we called our QoD *a Teen Roundtable*, and

asked six to eight questions, allowing teen co-designers to call out in a focus group format. More questions were posed in a *Teen Roundtable*, but by allowing teens to call out responses, we kept the time short while we maximized insights into the teens' awareness of various science topics.

Figure 1. ARG team creative writers videochat with teen co-designers to issue design prompts and give feedback.

Using professional, "real-life" partners to issue design challenges is a technique that is often used in Cooperative Inquiry (e.g., an international media company like Nickelodeon asks child co-designers for help) [27]. This technique served as an authentic learning opportunity for our teens. Several criteria exist for creating authentic learning scenarios: 1) learners should be presented with "real-life" problems that are personally relevant; 2) the scenario or design problem should not have prescribed or simplistic solutions; 3) the desired solutions could change attitudes, actions, or beliefs; and 4) the scenario should target a real audience [68]. From the outset, we emphasized to teen co-designers that they were contributing to an ARG that would potentially be played by thousands of teens, and that they would be collaborating with real professionals like writers from a transmedia production company and scientists from NASA. For each of our narrative and character design challenges, our creative writers issued the design challenge via video-conference and treated our co-designers as part of a professional writing cohort (Figure 1). Most of our field notes and session recordings showed evidence of the positive influence teens felt working with professionals: the teens "*lit up*," "*stayed focused*," and asked repeatedly when they might see how their design ideas would be incorporated into the live game. Weeks after the sessions had ended, one teen contacted the team to get an update on *DUST*'s launch date. Furthermore, they asked key questions about how we would credit their design roles and how they should include their participation in résumés.

Using video to conduct character interviews, share design ideas, and give feedback proved to be an effective design technique. Because our initial Bags-of-Stuff session resulted in few physical design props while sticky notes and group discussion resulted in a high volume of ideas, we focused on techniques that did not require teens to build low-tech prototypes. Instead, we sought techniques that allowed them to socialize and create collaboratively [45,65], such as using *shared videos* and *peer interviews*.

Videography is a common – and defining – aspect of adolescent life [12,50,51,65], and our use of it in design sessions proved an exceptionally powerful co-design tool for teens. During character design sessions, teens worked on character questionnaires modeled after those used in professional screenwriting [13], and then interviewed each other using these questionnaires. Adult co-designers or the teens themselves video-recorded these interviews and shared them with the ARG team's creative writers. The teens relished role-playing and responding to character design questions posed by their peer interviewers, and were especially excited when the creative writing team gave individualized feedback: "*their ears perked up every time they heard feedback that they could identify as their own*" (quote from field notes). The constructive nature of the feedback and playful green screen effects used by the professional production team were a big hit. The teens "*especially loved hearing their names called out specifically*" by the professionals (quote from field notes).

Co-designing Player Activities

In designing the ARG's interactive activities, we had the additional challenge of integrating opportunities to practice scientific inquiry in authentic ways. We expected that our teen co-designers would not act as content experts – nor would we need them to – in order to design activities and apps to help players tackle the science questions raised in *DUST*. Research in Cooperative Inquiry has shown that children's curiosity and questions about unfamiliar topics can help pinpoint areas for novel design features that promote their curiosity or scaffold the development of their expertise [11,60,85]. To frame their design task and give them examples of other tools that are used successfully by novices to engage in science investigation, we showed the teens several popular citizen science tools and communities. Although the design task was more challenging because our teens were unfamiliar with several science topics that *DUST* players would need to delve into (such as learning about neurological differences between adult and child brains or how genetic mutation occurs), these sessions helped us uncover the investigative process that teen players might follow to address gaps in their knowledge. Effectively, our co-designers posed questions and prototype ideas that focused our design team on features that would enable players to pursue similar questions during game play. For example, one teen wanted "*small devices to monitor and record sights, actions, brain activity*," and her sketches depicted jewelry-like, wearable sensors inconspicuously placed on the ears of in-game characters. Another teen proposed an app that allowed players to scan adults and submit them to a citizen science-like database that could be used to find a cure. These ideas contributed significantly to designs for a "health scanner app," a "microbe scanner," and a microbe web-app that players used in the final game.

Our use of storyboards may have contributed to difficulties that some teens had with this design challenge. Although many of our teen co-designers posed questions that

pinpointed possible app design features in their storyboards, others emphasized extending the narrative or adding more character backstories instead. These efforts reflected the teens' interest in developing *DUST's* immersive storyworld, but missed the mark in generating a variety of scientific-inquiry activities. Part of the issue may have been the technique. Storyboarding can be an effective technique with intergenerational teams [14,80], but because we framed the design goal as a "story," our teen co-designers may have been primed to continue working on the previous sessions' narrative-focused challenges. A positive side effect was that several of the stories demonstrated how game characters could motivate players to take action. For instance, one teen co-designer's storyboard urged players to "*to document EVERYTHING. If your friends or parents have these markings* [referring to an image in the storyboard], *show us. EVERYTHING IS IMPORTANT!*" We used language from these narrative-focused storyboards in the final version of *DUST*, with character-driven "Calls to Action" for players.

Co-designing the Player Community Site

Player collaboration is a key feature in ARGs, and we co-designed a player community site with teens to support this. We used Layered Elaboration [79] (Table 1), so teens could add their own sketches and notes to wireframes of the site.

Layered Elaboration proved to be an effective technique for teen co-designers. The structured, focused nature of the design challenge provided the right balance between constraints and open-endedness that allowed teens to maximize the number and quality of ideas they generated for the *CoLab* interface (as one of our teams dubbed it; a name we kept for the final game). Several of their design ideas were integrated into *DUST*. For example, in many large-scale ARGs, adult players will collect and share data that contain locational information – whether it is information on locations of clues or places that players are investigating. Our teen co-designers sensitized us to the fact that giving out GPS locations can signal "stranger danger" for youth, so nearly all of them asked for "NO GPS" indicators, or the ability to control who could see this data. In addition, and possibly inspired by infographics that they used in school assignments and achievements/badges in videogames that they played regularly, our co-designers wanted the CoLab to show narrative and play-based stats that players could collect and share. For example, because "*evil alien tardigrades*" was a theme that emerged in our narrative design sessions, teens wanted to include stats about "*Tardigrade Volume in the Vicinity*" as an indicator of imminent attack, and personal stats, such as how many science badges they had earned. Related to these visual indicators, our co-designers wanted to add a chatbot so that players could interact directly with an A.I. character that we had developed during our narrative design sessions. The teens wanted to test the A.I.'s "humanity" by asking it about human emotions and telling jokes. In addition, they wanted to chat with the A.I. to ask questions and direct it to collect or post data. All of these features became a key part of the final game's A.I. character, named IRIS ("Intelligent Research Information System"). Finally, teens added playful use of emojis to get and give peer feedback. This idea made its way into the final game as icons for peer-awarded "props" that players would give each other for posting evidence and questions that were "unique," "clear," or "collaborative," to name a few (Figure 2).

Figure 2. Peer-awarded "props" inspired by teen co-designers.

One of the most popular visual indicators from teen co-designers that we integrated into the final game was a "*Time-To-Collapse*" countdown widget. During narrative design sessions, we found that our teens defined "adults" as much older than most of the adult co-designers thought: teens estimated that youth did not become adults until they were in their mid-20s. This enabled them to design an older fictional NASA intern character whose science expertise players could tap, but also gave them pause about how long she had until she collapsed like the adults. They decided to monitor their community and individual "*collapse stats*" with a counter that would predict how much time each player might have until they fell comatose, like the adults. Our teens' "*Time-to-Collapse*" design included a "*Goodbye Status Wall*" where friends could post morbidly humorous, often playful farewells and "*in memoriam*" remembrances of those who collapsed before the game concluded (Figure 3). The widget became a prominent feature in the final game, and players posted comments to help encourage the community to find solutions, e.g. "*COLLAPSE IN 7 HOURS!!!!!!!! Am I safe? Did I get the TARDIGRADES? AHH! help. head hurts. will the tardigrades work in time?*"

Final Co-design Phase: Playtesting

Playtesting games has long been recognized as an essential step in the game design process [34,70]. Playtesting can occur at different stages in the design process, resulting in different types of insights. For example, Fullerton [34] identifies four prototyping stages (foundations, structure, formal details, and refinement), each of which is best conducted with different user groups at different prototyping stages. Playtesting can be valuable for exploring new game ideas, refining designs, and proving the effectiveness of games to stakeholders [39]. Though playtesting can require significant investment, benefits include identifying problems and new opportunities related to usability, quality assurance (e.g., finding technical problems) [25,61], and resolving conflicts between content experts, educators, and game designers [81].

ARGs provide unique challenges for game designers and we felt it essential to playtest *DUST* with our target audience. While prior efforts demonstrate the benefits of

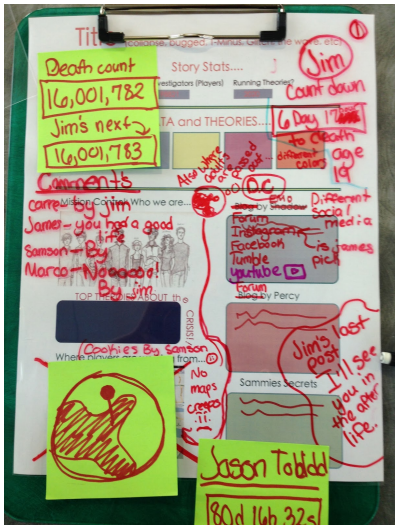

Figure 3. Prototype of Time-to-Collapse Widget and Status Wall.

playtesting, they have focused exclusively on other game genres, not ARGs. Moreover, we have found no documented playtests of large-scale ARGs with players participating from across the country in an informal learning setting. *Including members of our teen audience in playtests of DUST's field prototype supported our goal of co-designing with teens from conception to completion*.

Playtesting Process

Our playtest included two separate face-to-face introductory sessions held with different groups totaling 136 teens (13-15 years old), as well as three weeks of online participation and feedback collected from a total of 225 teen players from five different states. The two introductory sessions were conducted simultaneously in Utah and Maryland, allowing participants to establish a videoconference link for part of each session. Playtesters who did not attend a face-to-face session received instructions via email and/or direct contact with core team members. The goals of the introductory sessions were to 1) introduce what ARGs are and how they differ from traditional video games; 2) have players take a science activation survey (on their attitudes behaviors regarding STEM [52]); 3) get players excited about participating in an exclusive *DUST* preview; and 4) help players understand how to play. After the introduction, players could play independently for the next three weeks. We sent email reminders periodically, and several groups of playtesters met in after-school clubs, but most were left to play on their own, if and when they desired. This informal learning context for playtesting aligned well with how we designed the live game to be played. We held face-to-face recap sessions with a subset of playtesters, and also solicited feedback from players online.

Benefits of Shared Playtesting via Videoconferencing

Field notes from the introductory playtest sessions highlighted a few key insights about how to effectively introduce ARGs to teens. Findings focused on logistics, timing (particularly for the session that included a group of 70 students that was much larger than we had requested), participant frustration with taking the science activation survey, and technical issues faced in the early version of the collaboration platform. Of particular interest, field notes also emphasized the challenges and successes related to our use of web videoconferencing as part of the session. Web conferencing across time zones with a two-hour difference was hard to schedule and forced a rigid timetable: "*since we still had to connect with DC on video-chat, the timing was off.*" Furthermore, the session with the large group had participants in the back who had trouble hearing and being heard, and in one session there was a frustrating delay at times when showing the opening online narrative scene.

Despite these limitations, all participants dubbed shared playtesting via videoconference a success. Field notes describe students' excitement at seeing themselves on the camera: "*it was kind of like watching the Today Show fan window, or what happens when TV cameras descend in a small neighborhood - lots of waving at the camera and pointing and 'that's us!'*" The experience of remote video-conferencing was novel and most teens were excited "*to ask questions of playtesters across the nation*" (quotes from field notes). Overall, more than any other activity during the introductory session, the joint videoconference helped players experience the excitement of *being part of a community of players*, which is central to ARG play and motivation. While showing recorded videos of the other playtesters could have solved a few procedural challenges, it would not have had the live feel so prototypical of ARGs.

Improving Gameplay and Educational Scaffolding

Feedback from the three weeks of online playtesting and final face-to-face recap session revealed the same types of insights that videogames reveal. Issues that needed to be addressed included technical problems (e.g., mobile site not working; bugs), usability concerns (e.g., confusion on how to use some features like friending), and desired features (e.g., chat with online players; desire for more direct interaction with characters, or video content from them). Successes included *DUST's* trailer, the interactive story's graphic novel artwork (considered "*pretty awesome*" by all playtesters), and the social nature of the site that enabled friending and messaging other players and characters.

While the types of insights gained from playtesting *DUST* were similar to those gained from playtesting other types of games, playtesting an informal learning ARG for teens was essential because it allowed us to identify when and where our teen audience would need additional scaffolding to know what to do. The biggest concern raised by playtesters was that they "*got really confused as to what they should do and where to go*." They requested "*help*" buttons, suggested redesigns of the website to focus on calls to action, recommended creating a "*how-to-play guide*," and expressed concerns about "*what to do next?*" and "*how do we play?*" Because ARGs are a relatively new interactive experience that blends storytelling and gameplay, many of our playtesters had never heard of an ARG, let alone play one. Most ARGs have targeted adults who have more

experience collaborating and approaching unstructured problems [9,18]. In contrast, prior research has shown that ARGs designed for teens in small-scale, formal learning contexts require significant guidance [9]. This was demonstrated again in our own playtest of this large-scale, online ARG, though perhaps even more dramatically since instructors were not available to provide scaffolding during class time. While we anticipated the need for scaffolding, playtesting helped us identify specific requirements and techniques that we would not have realized otherwise. Playtesting with a large teen target audience (as opposed to game developers or older audiences such as university students) was critical because the level of scaffolding varies for different ages and audiences. Furthermore, playtesting in an authentic context (e.g., a self-guided, online experience as opposed to in-class or after-school with an instructor present) was essential because techniques used to scaffold gameplay and learning can differ based on context.

As a result of playtester feedback, several major changes were made to the *DUST* CoLab platform to help players know how to participate and what to do at various stages of gameplay. For example, originally, after logging into the site, players were directed to the main CoLab page that showed featured posts. While this seemed to make sense initially, we realized that players needed a more specific call to action upon arriving at the site. To accommodate that, we created an *Updates* page with a tab that focused on posts from IRIS, each of which included humorous memes, an explanation of recent story events, and most importantly an explicit call to action (e.g., "*Submit any #collapse videos of adults collapsing around you!*"; "*Collect more brain data with your Health Scanner app – #healthscanner!*"). We kept this "*Call to Action*" structure for the final game, and the *Updates* page became a primary mechanism for players to find out what was happening, whether from IRIS or other *DUST* characters. Another way we helped guide players was through the use of badges. Prompted by the need to provide players with motivation and direction on what to do next, the design team developed a set of badges that could be earned by individual players for completing various tasks. For example, the Avatarred badge is awarded when a player uploads a profile picture, the Opinionated badge is awarded when s/he has replied to at least 10 posts of other players, the Video Journalist badge is awarded when s/he posts a video about a certain topic with a specified hashtag.

Playtesting the Gamerunning Experience

An essential part of creating and launching an ARG involves gamerunning. ARGs are interactive performances that evolve as gamerunners interact dynamically with players. Playtesting *DUST* enabled our gamerunners, who included design team members and university students studying ARGs, to practice performing and interacting with teens. Playtesting helped us to identify techniques for coordinating the joint efforts of over 30 gamerunners; to improve tools and workflows used by gamerunners (e.g., creating/editing character posts); to gain a consistent approach for responding to players in ways that prompted them to develop scientific inquiry skills; and to create character content (most of which was used during the live game). Gamerunners developed a "*Gamerunner's Guide*" that was used to train gamerunners of the live game, and was also used by educators who later implemented a replayable version of *DUST*. Gamerunners also developed strategies and content that were used in the live game, such as a lead character's "*Week in Review*" posts that summarized the community's contributions to help players who joined late. Gamerunners used the "*Week in Review*" posts to spotlight specific players who demonstrated effective scientific inquiry practices as models for players who were unsure of what to do. Of note, one of our teen co-designers helped create the character who chronicled *DUST's* "*Week in Review*" posts, as the *"kid who is recording/journaling the game and 'making a story out of it'*" (field notes).

DISCUSSION

To gain design insights (*RQ#1*) and insights into teens' knowledge and attitudes about STEM (*RQ#2*), we needed co-design techniques to appeal to teens. Here, we focus on the types of co-design techniques that led to:

- Novel design ideas and features that resonated with *DUST's* teen target audience (in response to *RQ #1*); and
- Insights into teen abilities, knowledge, and awareness of STEM topics that informed how we designed *DUST's* scientific inquiry activities/resources (mapped to *RQ #2*).

The *structure* of each of our co-design sessions, such as opening with shared snack time to unwind and transition from a "formal" learning context to co-designing with friends, helped prevent the challenges that Isomursu et al. [42] experienced with teen interviews. The way we tailored the round-robin, single question QoD technique into the multi-question, focus group format of our *Teen Roundtable* supported adolescent desires to "hang out" and socialize [43], yielded a high variety of perspectives and ideas, and served as a useful, fun warm-up to the main design prompt of each session (*RQ#1*). While other co-design studies with teens have also used focus groups successfully [17], the STEM focus of our *Teen Roundtable* (*RQ#2*) proved very effective in drawing out teen attitudes and awareness of science topics (e.g., science jobs/disciplines, tools/approaches to investigate problems, ethical questions on experimentation and A.I.). These complementary parts, integrated into each weekly design session for eight weeks and also in our face-to-face playtest meet-ups, enabled us to develop a close co-design partnership with teens. Overall, our co-design session structure effectively blended multiple techniques, each one building upon the other to generate a variety of ideas and develop a comprehensive view of each design challenge, all packed into a 60-90 minute format.

Just as the *Teen Roundtable* allowed teens to hang out while informally discussing STEM topics, we found that using techniques that enabled teens to craft detailed *DUST* characters through *video-sharing and role-playing* were the

most generative in terms of features that were integrated in the final game (*RQ#1*). While we noticed that many teens struggled with low-tech prototyping techniques that work well with younger co-designers [37,80,85], all of our teens were excited to create collaboratively through *video-recorded peer interviews*, and they relished focusing on key aspects of narrative using professional tools like *character questionnaires*. Character and narrative development seems to resonate with teens in co-design projects [17,54]. While teens working with Mazzone et al. [54] also contributed to character design, *the professional questionnaires, peer interviews, and video-sharing approach* we used were distinct from traditional storyboarding techniques (*RQ#1*). Despite the level of detail and reflection required to work through character questionnaires, the teens were focused and engaged. We found that working *through* storytelling helped teens generate STEM-focused questions and calls to action that characters could give players in the live game.

Our *professional, real-life framing of the design context contributes to the theory of pedagogical praxis* [73], where educators and designers help children and teens engage in meaningful learning by inviting them to participate in real-life professional practice. Our teen co-designers were excited to be part of a *professional game production company* collaborating with NASA, an involvement that they realized they could use in résumés. We observed that being part of a professional community bolstered their interest in design as well as in science topics presented in *DUST* (*RQ#2*). Moreover, because online and mobile *video-sharing* platforms are more popular than television, and because corporations now offer sponsorship opportunities to young video creators [31], our use of *video-recording* and *video-conferencing* gave teens a sense of professional interaction and community (*RQ#1*). During playtesting, teens were excited to meet other teens via videoconferencing, which created *a sense of community* similar to what most successful ARGs achieve.

Adult ARG players thrive on the unbounded, distributed nature of transmedia experiences like ARGs [18]. In contrast, our co-design and playtesting sessions revealed that teens needed *extra framing and guidance to perceive and learn how to participate* [64] (*RQ#2*). This challenge is amplified when ARG gameplay requires teens to engage in science content and STEM practices that may be unfamiliar to them. By engaging our intergenerational team in a mini-ARG together in our introductory co-design session, we established a critical, jointly experienced frame of reference about the product we were co-designing (*RQ#2*). In addition, while playtesting is known to be valuable for many game types, it emerged as particularly important for ARGs because it allowed playtesters *and* gamerunners to fully experience the prototype, improve interactive features, and create content that could be used in the live game (*RQ#1*). *Playtesting* with our target demographic was essential for a learning-based ARG because the amount of scaffolding that youth need when compared with adults differs dramatically (*RQ#2*).

Often, during our design sessions, our teen co-designers would throw out seemingly silly, slapstick ideas [4] that at first glance, seemed to clash with our goal of creating an experience that exposed teen audiences to "real-life," "serious" science questions. However, the playful nature of design features like the *Time-to-Collapse* widget and emoji-inspired peer awards made the counterfactual experience of *DUST's* narrative more authentic to teens. Through a lens of learning, *play* and *performance* are considered new media literacies: play enables experimenting "as a form of problem-solving" [45:22] and performance allows learners to assume various identities "for the purpose of improvisation and discovery" [45:28]. By role-playing in *peer interviews*, our teens were engaged to "envision and collaboratively theorize about new worlds" [45:30]. By experimenting with various game interfaces through *layered elaboration*, our teens were able to "tap into play as a skill," [45:24], designing a *Time-to-Collapse* widget whose underlying algorithm could be mapped to neurological concepts that *DUST* presented to players (*RQ#1 and RQ#2*). Our teens' ways of infusing the real and the quotidian into the epic story that we designed together were invaluable meaning-making moments.

CONCLUSION

We have presented the co-design and playtesting process we followed to design a STEM-focused ARG *for* and *with* teens, from conception to completion. We gained insights on ways to craft techniques and design challenges keyed to the unique features of ARGs while ensuring that teens contributed their voices to the design of engaging characters and playful interactive elements. We also enhanced our understanding of how to frame design challenges for teens, especially in cases where they were not familiar or comfortable with science content. Our efforts contribute to ongoing HCI and learning sciences' efforts to involve teens in co-designing their own learning experiences.

SELECTION AND PARTICIPATION OF CHILDREN

We followed an informed consent process in accordance with US federal human subjects research requirements (45CFR46.102f). BYU and UMD Institutional Review Boards (IRB 622450-1) approved all letters/forms. Signed informed consent was garnered from parents for all of our 265 youth participants (225 playtesters, 40 co-design partners) who were under 18 years old. To ensure that we respected the rights of, and fully involved the 40 teens who worked with us as co-design partners, we also reviewed an assent letter with them that they could choose to sign (or not), regardless of parental consent. All of our teen co-design partners attended public schools in the US.

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