Digital Storytelling for Developing Computer Skills in Rural Appalachia

ANON

As we built and deployed a digital storytelling system to teach digital literacy skills to rural Appalachians, we discovered key opportunities and challenges to promoting digital literacy in this region. We identified that the importance of storytelling in Appalachian culture made digital storytelling an effective means of teaching these skills to residents. However, the poor technology infrastructure at our study site posed challenges to our participants' ability to use technology and learn new skills. We found that poor infrastructure reinforces low self-efficacy, discouraging participants from using technology. In environments where computers are often slow and unreliable, it is not possible to form realistic expectations of how a computer should act. Therefore, it becomes difficult for users to untangle if the issues they encounter are because of usage errors or the technology. These findings highlight how infrastructure and self-efficacy should be accounted for together when conducting rural HCI research.

CCS Concepts: • **Human-centered computing** → **Human computer interaction (HCI)**; User studies.

Additional Key Words and Phrases: Keywords

ACM Reference Format:
Anon. 2022. Digital Storytelling for Developing Computer Skills in Rural Appalachia. *Proc. ACM Hum.-Comput. Interact.* , CSCW (December 2022), 22 pages.

1 INTRODUCTION

In the work described in this paper, we built and deployed a digital storytelling system to teach digital literacy skills to residents of a rural Appalachian community. We describe the project's successes and the infrastructural challenges that we experienced during our deployment in the community's public library. Our work both continues and challenges aspects of the current trend in rural HCI to move away from a deficit model of describing what rural areas lack in comparison to urban areas [23–25, 33, 47]. Along these lines, rural HCI researchers have recently advocated to develop an appreciation and recognition for the opportunities and strengths that are unique to rural areas and cultures [23, 25, 33]. This socio-cultural perspective is certainly needed and extremely appropriate, and it is clearly unfair and inaccurate to ascribe the failures of technology adoption in rural regions to negative cultural characteristics and behaviors of the individuals themselves [5, 14, 24, 47]. However, in this paper, we seek to highlight the real and significant impacts of poor infrastructure on residents of rural areas.

That is, our work unpacks aspects of the research that rejects a deficit model, as we see ourselves separating cultural deficits and infrastructural deficits (even if they might impact culture). This is an important distinction in our minds, as a cultural deficit model implicitly places blame on the members of the culture, but an infrastructural deficit model recognizes the impact that the lack of a resource has on members of a culture. Specifically, we highlight the ways in which poor technology infrastructure has failed rural communities and reinforces negative self-efficacy for residents of

Author's address: Anon.

2573-0142/2022/12-ART
https://doi.org/

these rural communities. We suggest that rural computer users face significant challenges in forming positive perceptions of technology, because the technology that is available to them does not support a positive user experience. With a few notable exceptions [3, 6, 35, 36, 43], we have found that the prior work in rural HCI in the United States and other developed regions, has not fully explored the impact that poor infrastructure has on users' self-efficacy. In our experience throughout this project, we found that the slow and unreliable state of the infrastructure (i.e., slow internet connections and computers) creates a markedly *transformed* experience with technology, rather than a similar – but degraded – version of the experience. This transformed experience reinforces negative self-efficacy as users struggle to understand why their experience with technology is so negative, when it is framed positively throughout much of the nation and the world. Users perceive this transformed experience as being due to personal limitations rather than technical ones.

Despite these challenges, we found that using digital storytelling was successful in teaching our participants digital literacy skills. Our participants obtained new computer skills, and practiced existing skills, through digital storytelling. In part, we believe this is because storytelling is a deeply ingrained practice in Appalachian culture. This supports findings from prior work that states the importance of considering local culture when designing technology for rural users [5, 17, 20, 23–25, 47]. Our work extends this work by identifying a form of digital literacy education that is specifically appropriate for rural Appalachian settings and cultures. Appalachia is a geographic region in the eastern United States made up of 423 counties in 13 states [12]. Approximately 25% of the counties in Appalachia are designated as rural [39]. Rural Appalachia is disadvantaged compared with other rural areas of the United States when considering factors such as education, housing, employment, income, poverty, and internet access [39]. Of particular interest in this work is the digital divide present between residents of rural Appalachia and the rest of the rural United States. In rural Appalachia, 25.3% of households did not have access to broadband internet in 2015-2019, compared to 20.5% of other rural households in the United States [39]. Teaching digital literacy skills is increasingly important as Appalachia has been targeted by recent governmental efforts to extend broadband connectivity across disconnected regions based on these particularly low rates of broadband accessibility [29]. Therefore, as the connectivity improves, we must provide culturally appropriate and effective opportunities for digital literacy skills development to residents.

The primary contribution of this work is two-fold. First, we demonstrate that digital storytelling is a successful form of digital literacy education in rural Appalachia due to its cultural resonance. Second, we show how slow speeds and network unreliability reinforces negative self-efficacy and creates an entirely different experience of using technology for rural users, rather than a degraded version of the experience of users with reliable, high-speed computers and networks.

2 LITERATURE REVIEW

In this literature review, we discuss four topics of prior work in the field of HCI that hold particular relevance to our study and findings. First, we provide an overview of the current landscape of rural HCI research, summarizing the most recent considerations that have been suggested for researchers conducting HCI research in rural settings. Second, we discuss digital storytelling as a method of teaching digital literacy. Third, we discuss the most significant challenge we faced in this study - poor technology infrastructure at our study site. We summarize work from both developed and developing regions which also noted this challenge and go over the similarities and differences of this prior work to our own experiences. Lastly, we introduce key considerations from prior work on abstract representations of user experience, which have informed the interpretation of our findings. These works assisted us in analyzing our observations by giving us different ways of considering the facets of our participants' experiences.

2.1 Current Considerations in Rural HCI

Recent work in rural HCI has advocated for a positive focus, considering what opportunities rural communities hold for innovation, and what unique values they bring to the field. This contrasts with previous trends of focusing on the challenges they face or positioning their differentiated use of technology as negative [23]. Rather than designing systems for rural settings with the subconscious goal of bringing rural areas "up to speed" with urban ones, we should instead design starting with the rural perspective, and center our design on rural values, characteristics, and needs in the design process [24]. This alternative approach positions rural areas as different from, rather than less than, urban areas [24].

While this recent work has pushed the field to think beyond access and infrastructure [23], we believe that prior work may not have fully scoped the access and infrastructural issues faced by those in the rural United States. In their survey of the current landscape of rural HCI work, Hardy et al. [25] note that prior work has recounted how poor internet connectivity resulted in a negative user experience when using technology as part of a study. However, this prior work has not described in detail how unreliable or poor internet connections create an entirely different user experience for users in rural areas, which we observed in this study, and cannot be overcome through system design changes alone. The ongoing reality of detrimentally poor internet in rural areas of developed regions has not been fully recognized in recent literature in the field of rural HCI.

Most prior work in HCI has been conducted in urban settings with a focus on the characteristics and affordances of these settings [14, 23–25]. The impact of this disproportional focus on urban settings and the needs of urban residents is that technology is not as usable in rural areas. For example, rural settings tend to have a limited footprint on digital map systems, such as Google Maps, leading to negative consequences for tourism and business [14]. Prior work has highlighted how design choices intended to create a better user experience for users with high speed connections are made to the detriment of those on low speed connections [35].

To mitigate the issues that result from an urban focus in technology design, a key focus of prior rural HCI work has been cultural considerations of rural technology use [1, 5, 17, 20, 21, 47]. In addition to structural considerations for the design of technologies for rural use, values and cultural characteristics should also be a design consideration [5]. For example, through analysis of social media habits of rural and urban users, researchers found that rural users had distinct characteristics of use [20]. The authors suggest that rural users have different technological needs and researchers should conduct work to better understand those needs, rather than trying to force rural users to conform to a design that was built based on the needs of urban users.

Work outside of the field of HCI, but in the context of rural Appalachia, has also called researchers to consider specific cultural considerations of this region and its residents when conducting research there [19, 27]. Similar to calls from rural HCI scholars to disengage with cultural deficit models of rural areas, Appalachian scholars have called for the abandonment of the "culture of poverty" model of Appalachia which defines Appalachian culture as somewhat analogous to disadvantages experienced by residents, such as higher rates of poverty and lower rates of education [19, 27]. Instead, researchers call for consideration of true Appalachian cultural characteristics such as kinship, locality, community pride, privacy, humility, modesty, distrust of outsiders, and isolation [2, 15, 19, 22, 27, 37, 40, 44, 46]. Based on this prior work, we chose to use digital storytelling as a means of teaching digital literacy in this study because we believe storytelling aligns with our participants' culture. We also grounded the skills we aimed to develop in what the residents and local businesses wanted to learn and not what we think they should learn.

2.2 Digital Storytelling for Digital Literacy

Digital storytelling has been shown to be an effective purveyor of digital literacy [7, 10, 38, 45, 48]. Digital storytelling promotes digital literacy through use of technology such as voice recorders, video capture, word processing, as well as skills such as digitizing media, and communicating information [45]. Digital storytelling has been found to assist in the development of stronger digital literacy skills, and stronger reflective, communication, and critical thinking skills [48]. Chan et al. [7] noted thirteen distinct digital literacy skills concepts that their participants mastered through digital storytelling, falling within all three domains of their definition of digital literacy (digital competence, digital usage, and digital transformation).

Beyond teaching technical skills, digital storytelling accomplishes critical components of digital literacy by requiring those who engage in digital storytelling to morally and socially contextualize their story content and their presentation of their story [54]. Because of this quality, digital storytelling has been used to achieve cross-cultural understanding among participants [11, 49]. Digital storytelling also inherently valorizes personal narratives, aligning it with our secondary goals of historical cultural preservation and community empowerment [4, 49, 53]. Therefore, we determined digital storytelling to also be an effective means for achieving our primary goal of digital literacy education within our rural Appalachian study site. Prior work in Appalachia has utilized digital storytelling, with socio-cultural goals of achieving the benefits we have discussed here, but not with a strong focus on promoting digital literacy [49].

2.3 Infrastructural Barriers to Technology Use

Prior work has identified specific network speeds and response times as unacceptable for the user experience [9, 52]. For example, Chetty et al. [9] describe network speeds of 2 Mbps as "detrimental for the overall internet experience" and note that the FCC's goal is for all American broadband users to have minimum network speeds of 100 Mbps download and 50 Mbps upload [9]. Tolia et al. identified response times of 5 seconds or more as being "unusable" [52]. In our work, we regularly observed these "detrimental" and "unusable" speeds, and this is not unique to our research site in rural Appalachia. Burrell [6] noted similarly low speeds and high costs when working with a rural community in California. Our work provides additional evidence that poor infrastructural conditions are a widespread phenomenon across the rural United States.

While we believe that our observations highlight a unique way of understanding the experiential differences caused by poor infrastructure, we build upon prior work which has noted structural barriers to effective technology use in rural areas [3, 6, 8, 16, 18, 21, 25, 26, 31, 34–36, 41, 43, 50]. Prior work in settings throughout countries with highly developed technological infrastructure (e.g., the United States, Canada, and Australia), has found that network unreliability is often perceived by rural residents to be the most critical issue with their technological infrastructure [6, 35, 36, 43]. In these studies, stability of connection was more important to users than connection speed – a reliably slow network is better than an unreliable network that goes in and out of working. For rural residents, internet access is unreliable and expensive, resulting in an experience using technology that may be surprising for many non-rural residents. There is also a cyclical problem that the qualities that attract high-speed internet deployments are halted by the lack of existing high-speed internet (population density, economic opportunity, etc.) [35].

As Hardy et al. noted in their overview of rural HCI work [25], a significant amount of rural HCI research has been conducted in contexts in the developing world [8, 16, 18, 26, 31, 34, 41, 50, 56]. Wyche has noted that the field would benefit by highlighting similarities between users in developing world contexts and developed world contexts rather than positioning them as different from one another [55, 56]. In our review of prior work conducted in rural settings in the developing world,

we found strong similarities to the conditions present in our own US-based research site. Regarding work conducted in Uruguay, Hourcade et al. note that the connectivity issues they observed "may seem trivial to those in developed regions," but this is not the case, as we found that connectivity issues also pose major challenges to residents of rural areas in a developed country like America [16]. Another prior study noted the challenges of web browsing in the developing world where internet is slow and/or cost prohibitive and page loads can take up to 240 seconds [8]. These speeds aligned with those we observed in our work. Participants in Chen et al.'s study [8] multi-tasked to pass time when page loads were exceptionally slow but this was only moderately helpful in alleviating their frustration. As we highlight in more depth in our findings (Section 4.3.1), our participants had a similar experience. A study conducted in Brazil highlighted the challenges of designing a system that is usable by people with varying levels of digital literacy [1] – a challenge we have also encountered in our own work. Based on our experience and readings of these prior works from developing world contexts, we agree with Wyche that experiences using technology of rural residents in all settings may have strong similarities. Efforts to address rurality-based digital divides in developed contexts should bolster work with similar goals conducted in developing contexts and vice versa.

2.4 Abstract Ways of Considering the Rural User Experience

Other works have helped to inform our understanding of our observations by providing abstract representations of user experience and different ways of thinking about rural user experience of technology [13, 30, 32]. In our discussion, we draw from these works to demonstrate how poor infrastructural conditions can create a transformed, rather than just degraded, user experience with technology. Lindley et al. [32] held a workshop on considerations of time in the field of HCI. This has informed our work by giving us unique ways of considering the implications that slow technology response times hold for rural residents. Similarly, Costello's work on rhythm [13] has given us a richer understanding of potential somaesthetic differences in users' experience with technology based on infrastructural limitations. Hu et al. [30] provide considerations for inequities in user experience based on socio-economic status differentials. This holds implications for rural HCI work because of the ways that income and rurality are linked, with many of those living in the most remote, rural regions also being low-SES [28, 51]. Some facets of technology use and SES highlighted by Hu et al. have been particularly apparent in our observations, such as technology self-efficacy and access to reliable technology. Considering our observations through these facets of use helps us to break down different impacts that cultural perceptions of technology and infrastructural barriers have on our participants' experience of use.

3 METHODOLOGY

3.1 System Design

In our preliminary research activities, we spoke with local residents, educators, employers, and workers at the local career center to determine the most in-demand computer skills for Appalachian job-seekers. Based on these preliminary discussions, we found that when people talked about "computer skills," they often considered internet skills to be a necessary component of basic computer skills. Early attempts in our research at this site to deploy offline digital literacy tutorials were unsuccessful. The interactivity afforded by the connectivity of this tool was a significant draw for participants. Therefore, we decided to develop a tool which would teach introductory web skills such as opening a browser, navigating to a website, filling out a form, and utilizing basic multi-media audio recording and playback tools. At the time we initially developed this system, we purchased a router for use at our study site to try to avoid the types of network-related challenges

we describe in this work. One reason that failsafe did not work for us is because of the unexpected unreliability of internet speeds at our study site. When we tested our router speeds ahead of deploying this tool at our study sites, we experienced speeds that would have been acceptable for the site we developed. Unfortunately, at the time that this study was run, we experienced extremely poor network speed on this router, resulting in the poor experience of use that we describe here.

The design of the storytelling website is intentionally simple, using as few multi-media elements as possible, as we knew that we were designing for an area with poor network speed. We expected stories recorded into the system to be less than 5 minutes long and the upload component of our system design was built to be compatible with a file size of a 5 minute or less story and the anticipated network speeds. That said, uploading audio simply takes a lot of bandwidth in the context of a low-speed connection and we experienced problems with the network during the evaluation and had to rely on our backup plan (using a handheld recorder and later importing it into the system). Since the evaluation, we have implemented more fail-safes on the system, i.e., if the network fails, we have a copy of the audio saved to the computer and it will upload to the server through a combination of scripts and using a Dropbox folder to upload as the network is available. The system uses a Django backend [1], with a PostgreSQL [2] database, and an HTML / vanilla JavaScript frontend.

3.2 Study Procedure

3.2.1 Background. This study is part of a larger project to teach rural residents digital literacy skills needed to obtain better employment. The key sites for this project are public libraries in a small, rural county in North Central Appalachia. Public libraries are valuable resources for internet access for many rural residents [42]. We conducted preliminary work including: interviews to determine in-demand skills for local jobs; workshops to understand current computer skill level and desired skills of community members; and installation of a higher speed internet router at the public library in our primary research community to support research activities. Based on our findings from this preliminary work, we built and deployed several modules. In this paper we present our story recording module, which is meant to teach web page use, form data entry, and audio recording/playback. Participants used this system to record stories of local history. These stories are then auto-transcribed by Google transcription services and uploaded into a Microsoft Word plugin which uses the stories and audio recordings to teach participants basic Microsoft Word skills and will be used in a future phase of this work.

3.2.2 System Deployment. To observe participants using our system and gather their feedback, we scheduled 30 minute time slots with participants over two days - one weekday and one weekend day - in November, 2021, at the public library in our research community. Participants were recruited via a sign-up sheet at the public library which was set out approximately one week before the sessions were to take place. The librarian assisted in recruiting by informing library patrons of our research activities. This study and our COVID-19 protocols were approved by our Institutional Review Board.

In total, we had 9 participants record a total of 18 stories. These 9 participants are members of the local community and account for approximately 1% of the town's total population, which is approximately 900. Computers were located in each of the library's two rooms to enable two participants to record stories simultaneously without interfering with each other. One researcher was present to assist participants. During each time slot, the researcher showed participants how to use our system to record their stories and observed their interaction with the system. Participants

[1] https://www.djangoproject.com/
[2] https://www.postgresql.org/

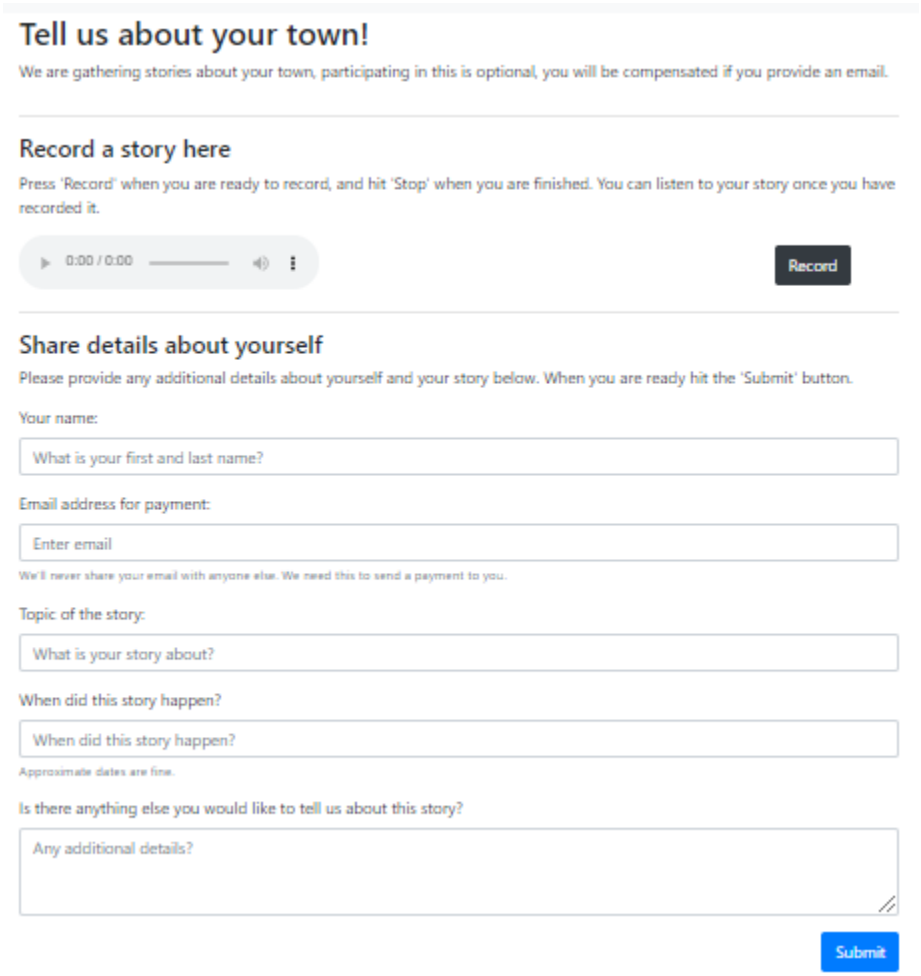

Fig. 1. The story recording website developed and deployed in this study

were instructed to use our system to tell their stories, play back the stories to ensure the recording captured correctly, and then fill in additional details about the story in the form. All participants required some instruction about how to use the system beyond the instructions provided on the webpage. After this initial instruction about system use, the researcher stepped away to allow participants to use the system independently. At that point, the researcher only assisted participants again if the participants engaged the researcher to ask for help with system use. Participants were compensated $5 in cash per story they recorded. Stories were between 1 minute and 11 minutes long, although the majority of stories were around 5 minutes long.

In case the system recorder functionality failed in any way, as we were wary of the network going down at the library, we also captured participant sessions on digital audio recorders as a backup. Participants' sessions interacting with the system were audio recorded and manually transcribed by the authors. We took notes on non-verbal observations made during participant sessions. We also noted down any quotes from participants before or after their sessions interacting

with the system and that were not captured on the audio recorders. Participants were made aware through the informed consent process that they would be recorded, including interactions with the researcher outside of their use of the system. We iteratively coded audio recordings and researcher notes through processes of open coding and deductive coding, and both of the authors reviewed these codes together to ensure agreement. This resulted in the four key themes we highlight in our findings. To protect our participants' privacy, we use gender specific pseudonyms to refer to them in the vignettes through which we present our findings.

3.3 Participants

Of our nine participants, eight could be considered elderly, falling between the ages of 65 - 90. The one participant who was not elderly was between 30 - 50. Participants had varying experience with computers which did not necessarily align with common patterns of age and tech savvy. For example, our oldest participant, referred to as Sharon in this paper, was an experienced computer user. Sharon had worked with computers in her career and considered herself to be a skilled typist based on her experience doing data entry and transcription work. Our youngest participant frequently commented on his discomfort with computers and referred to himself as computer illiterate. These types of comments were common among our participants and even Sharon expressed a dislike for computers, despite her relatively high level of experience using them compared with most of our other participants.

Most of our participants indicated to us at some point that they did not see themselves as skilled computer users. We heard this from a variety of participants, and below is a list of typical comments.

> Ellen: "I'm not computer literate at all"
>
> Researcher: "Do you know how to open MS Word on [the library computer]?"
> Jane: "At home I can, but I don't know about here"
>
> About typing information into the form, Nancy: "I don't know if I'm very good at that"
>
> Gordon: "All this computer stuff is great, it's the trend, it's where things are going, but I'm just not [suited] for it as much as I'd like to be."
>
> Sharon: "The most aggravating thing ever invented was the computer."

Participants also had varying experience using computers and other ICTs. Some participants reported having computers at home and some had experience using smartphones. Others had flip-phones or indicated that they did not have a computer at home. One participant, Patty, was a skilled computer user and told us that she had led computer training courses for the elderly in the past. Participants indicated a mix of experience using computers, smart phones, and tablets and few participants shared the same profile of experience with ICTs.

Three of our participants indicated that they had experience with the skills needed to use our system. Referencing spellcheck, Jane told us:

> Jane: "When these are underlined, I know how to fix those."

The different ways in which participants engaged with ICTs in their regular lives did not seem to align with their self-efficacy or ease using our system. For example, considering Sharon again, who was one of our most skilled and experienced computer users, she did not have a computer at home or a smartphone. Other participants who had smartphones or computers at home had low self-efficacy or required significant help using the system.

4 FINDINGS

Through our observations of participants' use of the system, we identified four key themes. First, we found digital storytelling to be highly culturally resonant. Second, we found that use of our system and digital storytelling effectively taught computer skills to our participants and allowed them an opportunity to practice existing skills. These two themes represent positive findings from this work, demonstrating the effectiveness of digital storytelling for digital literacy for an Appalachian audience, and are presented together in Section 4.1. Third, we found that participants experienced barriers to using technology. These barriers were often highly interconnected but included low self-efficacy, lack of technical experience, misalignments between system design and participant use, and poor infrastructure. Finally, we found that slow and unreliable computers and networks at our study site had significant negative impacts on our participants' experience using technology. We observed that these poor infrastructural conditions did not just result in a degraded user experience as compared to the experience of using reliable, high-speed technology, but transformed the user experience. This transformed experience seemed to reinforce participants' low self-efficacy, resulting in a vicious cycle through which rural residents are less likely to develop digital literacy. As evidence of these findings, we provide vignettes where we outline the context, the participant action, and supporting quotes describing our observations.

4.1 Cultural Resonance of Storytelling and Obtained Skills Through System Use

We chose digital storytelling as a means of provisioning digital literacy in part because it seemed to resonate with rural Appalachian culture. Based on our observations, this turned out to be more true than we had anticipated. Many of our participants described themselves as storytellers and told us about the importance of storytelling in their lives. One participant, William, provided us with CDs of stories and songs about local culture that he had previously recorded at a studio in an adjacent town. He also told us that he is a member of the West Virginia Storytellers Guild. Another participant, Sharon, shared that the stories she recorded for the system had previously been submitted to short story competitions. In one story that the participant Jane recorded, she described her grandfather, the "tale teller." In the story, she recounts a time that she asked him how long he had been telling tales and he replied, "about 72 years." This notion of storytelling being a tenet of participants' lives and culture was a recurring theme through our observations and interactions with them.

Participants' interest in storytelling often directly aligned with their prior experience using computers and other ICTs, or motivated their interest in learning to use computers. For example, William had experience with audio recording and playback because of his prior experience working in radio and in the West Virginia Storytellers Guild. He told us he would like to learn more computer skills, but his existing skill set allowed him to use our system smoothly and without issue. Nancy shared that she was interested in using computer skills so that she could write her stories, music, and poetry more easily. During her session with us, Nancy learned and practiced introductory computer skills such as how and when to use left and right click buttons on the mouse, how to locate and use punctuation with a keyboard, and what the cursor is.

We found that participants obtained computer skills through use of our system such as using an audio recording and playback widget and navigating a form on a web page. Four participants learned additional specific computer skills through use of the system.

Sharon was an example of someone that learned about using volume controls, Sharon commented on the volume when she was playing back her story:

> Sharon: "Oh that's way too loud."
> We showed her how to lower the volume using the volume control keys on the keyboard.

We observed Sharon using the volume controls on her own later in her system use session. It is easy to discount learning these basic skills as trivial, but we want to stress that these types of skills are real barriers to feeling in control of a computer and learning more advanced skills in the future.

Sharon, Nancy, and Gordon learned to use the spellcheck function native to Microsoft Edge:

> Gordon: "You don't have spellcheck on this thing, do you?"
>
> Seeing a red spellcheck line under a word typed into the form, Nancy: "Uh-oh, what do I do there?"
>
> Sharon: "This is a fictitious story but I don't know how to spell fictitious."

After this interaction with Sharon, we observed that she used spellcheck on her own later on. Nancy and Gordon did not have any other misspellings where they would have needed to use it.

4.1.1 Vignette 1 - Gordon. Gordon emphasized the importance of storytelling in his own life, describing it as a "compulsion" and saying,

> Gordon: "When I'm by myself, when I have the coffee just right and the dog's not bothering me, I can write...and it's like therapy."

He recorded several stories in our system that intertwined his family history in Appalachia and his time traveling overseas during his career in aviation. This use of storytelling both for reinforcement of local culture and cross-cultural education came up again in his descriptions of how he integrates his love of storytelling into his current work as a school bus driver:

> Gordon: "I'm a school bus driver and I've been trying to, tactfully, in short bursts, enlighten the students that this area is absolutely up to here in history and nobody acknowledges it or claims it...When I do my school bus, I pick up these kids and I try to greet them in Spanish, French, German, etc...Those kids that's running around here, they're so, sheltered is the wrong word, but isolated, and it's just my little way of letting them know there's something out there on the other side of these mountains."

This description of his intentions with storytelling aligns with our goals of using digital storytelling for this project. We chose to center our system around storytelling with the goal of preserving artifacts of Appalachian history and culture, as well as promoting cross-cultural understanding. This resonated with participants, as these goals aligned with their own attitudes and practices of local culture, and therefore, are natural for our participants to engage with in their use of our system.

4.1.2 Vignette 2 - Nancy. Nancy was another participant with a particularly strong connection to storytelling:

> Nancy: "Music, writing, it's my passion"

During her session with us, she recorded a children's story she wrote. She also showed us a children's book she had self-published through a local printer and which is kept in the library. Nancy had very little prior experience using computers and during her session with us, we worked on skills such as using left and right click with the mouse, locating the cursor on the screen, and typing with the keyboard:

> Researcher: "[To begin recording] you will click the record button."
> Nancy: "Click it with that?" Referencing left mouse button
> ...
> Researcher: "Go ahead."
> She clicks with right click and begins telling her story.
> We stop her because it did not record and explain to use left click.

She clicks it twice with left click and begins telling her story.
We stop her because it started, and then stopped, recording due to the double-click, and we tell her to click just once.
She clicks it once with left click and tells her story.
[...]
After recording her story, we tell her to complete the form data with the keyboard.
Nancy: "I don't know if I'm very good at that."

As she filled out the form, she wanted to insert an apostrophe in one of the words in the title of her story. We had a series of trials and errors in using backspace, delete, and other keys on the keyboard to accomplish this. Through these experiences during Nancy's story recording, she learned how and when to use left and right click buttons on the mouse, how to locate and use punctuation with a keyboard, what the cursor is, and how to use spellcheck. However, she did not seem to perceive story recording as teaching them computer skills, although she had learned specific skills and practiced existing skills. After her system use had concluded, we got to chatting about some of the goals of our research in the community and she sighed, saying,

Nancy: "I need to learn how to use a computer."

She did not realize that the activity she had just completed had been teaching her that. Other participants made similar comments after completing their system usage. We posit that storytelling was such a natural part of our participants' lives and culture, and their self-efficacy with technology was so low, that it was not clear to them that they could be learning digital skills by doing an activity that felt natural to them. In some ways, this was helpful, because the cultural resonance of storytelling helped to dissolve attitude-based barriers to learning to use computers. However, it was also somewhat counterproductive as participants did not seem to appreciate that they were learning to use a computer, which did not increase their feelings of self-efficacy. In future sessions, we may need to summarize what the participants have accomplished in person or through the interface.

4.2 Unpacking the Barriers to Technology Use

Throughout our observations of participant usage of our system, we encountered many different, intertwined barriers to technology use. These barriers were in regards both to use of our system, and of technology more generally.

4.2.1 Vignette 3 - Ellen. In this vignette Ellen, who self-described herself as "computer illiterate", was also learning how to adjust volume. Ellen's experience using the system highlights several of the interconnected barriers to learning these skills. When it is difficult to make the computer do what feels like a basic operation, it is easy to feel frustrated:

Ellen: "I've got a problem. I paused it at 5 minutes and I went to play it back but I couldn't hear anything, so I started reading again but I noticed the time wasn't..." She trails off.
Researcher: "I'm turning up the computer volume."
Ellen: "But I did that, look, I thought maybe it wasn't turned up"
Ellen had toggled the mute button on the system playback widget.
Researcher: "I think that might have just turned the sound off."
After we adjust the volume, we tell her that she will have to record her story again, because clicking record a second time overwrote her first recording.
Ellen: "From the beginning?!" she sighs.

Barrier 1: Low Self-Efficacy Before she even began using the system, Ellen informed us that she believes she is "not computer literate at all," which demonstrates her low self-efficacy as a potential barrier to use. As prior work has noted, low self-efficacy can prevent users from using technology because they may have a high tendency to blame themselves and give up quickly if problems arise [30, 57]. Despite her expression of low self-efficacy, we did see in this instance that Ellen attempted to problem-solve on her own before asking for help, demonstrating some level of belief in her ability to use computers. However, as we will go on to discuss here, in this case, if we were not available to help resolve the issue, she would have likely given up after she had exhausted her options and would have reinforced her low self-efficacy.

Barrier 2: Lack of Experience/Mentorship with Computers We are hesitant to call this a 'barrier' as the intention of our research is to help low-tech-literacy participants obtain technical skills. Ellen also did very well by trying to resolve the issue she encountered on her own before calling over the researchers to help when her attempted solution did not resolve the issue. In a situation where the researchers, or other more experienced computer users, were not present to assist her in resolving her problem, this issue may have halted her system usage altogether. Therefore, it is still worth recognizing that lack of experience and, more importantly, lack of available help, could pose barriers to system use and general computer use in our participants' daily lives.

Barrier 3: Design Conventions The last barrier we identified in Ellen's session was some of the conventional design decisions that we made, sometimes without realizing it. That is, there were clear deficiencies and misalignments with our participants' expectations and desires, and these had a greater consequence to these users in this context. Our system design - and the constraints of the local internet speed - allows for stories that are a maximum length of around 5 minutes. We did not put a hard restriction on this, not realizing that anything recording much longer than 5 minutes would clog the connection. That is, most participants' stories fell into this 5 minute time range, but a few went longer which led to system failure. Ellen respected this request, and stopped telling her story around 5 minutes. That said, we did not think to include a 'pause recording' button, which led to additional frustration for this user. We mis-modeled the manner in which participants would record their stories, as we did not anticipate the amount of preparation and thought that they wanted to have. We thought of it as a very low stakes process, but participants did not. Instead of being able to resume her recording when we informed her it would be okay to record in one file, she had to re-record the full story from the beginning. This is because our initial system design only had 'record' and 'stop' functions where each new recording would overwrite the last one. While these types of problems are frustrating to skilled users, for our participants they are experienced as even more so, specifically (1) the participants seemed more widely discouraged about computers by the frustration with our system and (2) they directed much of the blame to themselves, instead of on our poor design decisions (where the blame truly lay).

4.2.2 Vignette 4 - Gordon, Sharon. Elaborating on *Barrier 3*, participants interacted with our system in unexpected ways, due to misalignment between our expectations and that of participants. One way in which this importance manifested in participants' use of the system was that 7 out of 9 participants brought written copies of their stories to read aloud. We anticipated a much more relaxed attitude about story telling. The workflow we designed transcribes the audio recordings of stories into Microsoft Word documents which participants can then review and edit for accuracy. Considering that the majority of their stories were already written down, this workflow likely seemed redundant at best. We posit that this misalignment in expectations of design and use reflects a misalignment in perception of the importance of stories because we expected storytelling to be a more casual activity for our participants, as well as participants' level of comfort with computers. In our system design, we had thought about the storytelling component of our study as more of a

means to an end – stories had to be recorded to be transcribed into Word files where the real system use would begin. In reality, storytelling was the main attraction for our participants. Our envisioned use of the system involved a participant recalling a story in the moment of using the system, and telling it from memory. In reality, our participants were practiced and careful storytellers. Even those who did not bring written stories to recite for the system desired a pause recording function to be added to the system so they could stop to think about how they wanted to phrase parts of their story. Participants also wanted the ability to re-record small segments of their stories when they were unhappy with their delivery. For example, after hearing the system use instructions, Gordon asked:

> Gordon: "So if I stutter or think of a better word, I can go back and change it?"

We had to tell him that was not possible, but that he could note in the form if he made any significant mistakes that he would like an editor of the story transcription to change. Similarly, Sharon encountered a mistake when listening back to her story recording:

> Sharon: "I messed up on a name so how will [the people who edit the story] know what to put there?"

We told her that there was a section in the form for noting additional information about the story where she could include the correction, but a more elegant solution would have been to allow her to record over the segment where she made a mistake to correct it before it was transcribed. Making inaccurate assumptions while designing systems and interfaces for users is relatively common (at least in our experience). However, the consequences of these errors, and how the participants experienced them, felt different to us because of the implications they held for participants' broader perceptions of technology.

4.3 Impacts of Poor Internet Access

The library network support for the state of West Virginia told us that the library where we are conducting our research pays $500 per month for a 2 Mbps connection. This is split across the library computers and the public WiFi. Often, the public WiFi at the library is slow enough that we are unable to capture a speed test but, when we have been able to, public WiFi speeds have been between 0.1-0.5 Mbps. We do not know the underlying data link of this connection, but the available internet providers in the area offer DSL, cable, and satellite connections. Because this connection was prohibitively slow for our intended research activities, we installed a 4G LTE router at the site that is advertised to have speeds between 20-50 Mbps. However, the cellular service is highly unreliable in the town and, at times, achieves speeds no higher than the library's public WiFi, or drops completely. Many participants in our study and the residents generally of the community do not have internet at home and rely on the library's internet for activities like doing taxes or schoolwork. One participant with home internet noted that her connection at home is also slow.

We also provided computers to use for our research purposes so that we could develop, test, and install software we developed at our discretion rather than being limited to using the public access computers located at the public library. The computers we provided are modern all-in-one desktops but do not have particularly state of the art specifications as we wanted them to be similar to the public access computers at the library and computers that our participants may have at home. These computers were running Windows 10 and we used updated versions of the Chrome and Edge browsers. We updated these computers regularly, and ensured they were fully updated before setting them up at our study site. Based on the fact that we tested our system on the exact hardware that participants used in this study, we know that the infrastructural issues we faced were related to network infrastructure, rather than the computers themselves. Therefore, when we

refer to "infrastructure" and related issues and barriers throughout this paper, we are referring to internet network infrastructure.

Our participants exhibited frustration at the computer and frustration with themselves as they tried to understand if the issues they experienced were caused by the computers' slowness or their own lack of technical skill. For example, we frequently ran into issues teaching participants how to use the *record* button because the poor network speeds caused it to act unpredictably. In our design, the *record* and *stop* functions were held within the same button that would toggle between the two labels and functionalities based on which option was available – a relatively standard design that is not a problem on reliable connections. The button would stop the recording if a recording was ongoing and, if the recording function was stopped, it would start a new recording, overwriting the last recording. However, given the slow network the button would sometimes change after several seconds and not visibly change to indicate that the button click had worked. Participants, reasonably, assumed it had not registered their first click and would click it again, sometimes a few times. Eventually, all clicks would process, starting, stopping, starting again, stopping again, etc. At times, this resulted in false starts, where participants would begin speaking, thinking the recording was going, and would realize it actually had been stopped. Another, arguably worse, outcome was that some stories were wiped after having been recorded and had to be re-recorded.

Because of participants' already low self-efficacy with computer use, they often assumed it was they who had done something wrong, despite having acted completely rationally, and the blame instead lay on the slow network. Prior work has identified response times of >5s as "unusable" [52] but this is typical for computer users in this community, and likely a significant portion of rural Appalachia. Developing self-efficacy with technology becomes a nearly impossible task when computers are consistently acting in unintuitive and frustrating ways. Computer users in this region do not have the opportunity to develop a mental model of computers working well. Therefore, they do not have this model to fall back on when network speeds or outdated devices create a poor and unintuitive user experience. Their experience using computers is not only a degraded version of computer use in non-rural or otherwise high-speed environments, but a different, transformed experience altogether.

One of our participants summed up the experience of trying to interact with these computers and waiting so long that it became unclear if the computer had registered the request after submitting her story recording:

> After clicking submit, Nancy: "What are we waiting for?"

4.3.1 Vignette 5 - Sharon. During her session with us, Sharon shifted between blaming the computer slowness and herself for problems she encountered. The problems we observed her encountering stemmed from the infrastructure issues at our research site that caused excessive computer slowness. This situation demonstrates us how difficult it is for participants to develop self-efficacy with computers, when infrastructural barriers cause the computer to react in unpredictable and frustrating ways.

Sharon began her session with us by stating, while waiting for the page to refresh:

> Sharon: "The most aggravating thing ever invented was the computer."

The reason for her exasperation became clear as we observed her trying to use an excessively slow computer and internet connection over the course of her session recording three stories. The first time that she encountered an issue caused by slowness occurred when she tried to start recording her story:

> Sharon clicks record. She waits a few seconds and it doesn't respond. She clicks it again and it shows that it is recording. She begins telling her story. This action was

> not actually in response, though, to her second click, but was a delayed reaction to her first click. The second click registers shortly after she has begun speaking and the recording stops, but she does not realize. We stop her and tell her what happened and ask her to click record just once and start recording again.

In this scenario, Sharon acted as a rational computer user would when using a computer with the kind of high speed that is standard for most non-rural users. However, her experience using computers is with the slow and outdated devices and connections that are available in this region, resulting in the kind of unpredictable behavior from the computer that occurred here. Therefore, it can be difficult to develop self-efficacy when troubleshooting attempts (such as clicking a button a second time when it seemingly doesn't respond) can be punished with undesirable outcomes (such as the recorder unexpectedly stopping mid-use).

After she had finished recording her story and had moved on to filling out the form, she encountered another frustration related to computer slowness while learning to use spellcheck:

> Sharon: "This is a fictitious story but I don't know how to spell fictitious"
> We show her how to use spell check by telling her to try to spell it and right-click on the word if a red line appears beneath it.
> Sharon clicks the word and waits 5 seconds before asking: "Do I need to right-click it?"
> We say yes and she right-clicks it.
> After another 5 seconds, the menu appears in response to her right-click and she selects the correct spelling.
> In the 10 seconds we waited for the computer to respond, we made small talk about the story she recorded. She remarks: "I wish this was faster."

In this instance, she was still, rightly, placing the blame on the computer for her poor experience when she said "I wish this was faster." Rather than attempting a troubleshooting solution on her own as she did in the first instance, this time she verified that she should right-click instead before trying it on her own. This was also already after she had waited 5 seconds, a period of time that would be unacceptable to wait for a click to register for users on high-speed connections. At this point, her experience using our system has demonstrably taught her that trying to solve problems in ways that seem intuitive to her can result in frustrating outcomes and that computer use entails a great deal of wait time. Supporting findings of prior work, we multi-tasked to pass time by chatting when the computer's responsiveness was excessively slow, but this was only moderately helpful in alleviating frustration [8]. It is worth noting here that the computers the participants were using were provided by us, and that their performance was acceptable on higher speed connections in our lab and office. It seemed to us that the operating system relied so heavily on stable connections (e.g., Microsoft Word seems to do a license check via the network as it launches), that the entire computer operated more slowly.

At other points of her session using our system, we noticed her self-blaming for issues that she encountered resulting from computer slowness:

> Sharon: "I can't get this off of here [referring to text in the form]. I pushed delete but it didn't delete."
> We show her how to use backspace, mistakenly thinking that she tried to delete text behind the cursor. In reality, the delete request had not yet registered. Soon, the deletions start to register.
> Sharon: "Well, I probably deleted a whole bunch...*laughs*...I did, didn't I."

In this instance, she shifts from using language that blames the computer to using language that blames herself, lamenting that *she* deleted more text than she had intended, rather than saying the computer did so.

At another point in her system use that we were not present for, but heard on our recordings later, she once again used self-blaming language, although we are not sure what issue it was in reference to:

> Sharon: [encountering an issue that we were not present for] "What did I do?"

From these observations, we could see how closely tied poor infrastructural conditions and low self-efficacy are when using computers. When acting rationally and intuitively, in ways that experienced computer users would act when troubleshooting issues on standard high-speed computers, those actions resulted in issues, reinforcing feelings of low self-efficacy. If these sessions had been somewhere with a high speed internet connection, the participants would have been rewarded with the correct result from the computer. When one's only experience of using computers is under poor infrastructural conditions, it can be difficult to untangle if the computer or the user is at fault when things go awry.

4.3.2 Vignette 6 - Jane. In an attempt to show Jane the second phase of this study, where automated transcriptions of recorded stories would be available to be edited in Microsoft Word, we encountered a significant instance of slowness:

> Researcher: "Do you know how to open MS Word on [the library computer]?"
> Jane: "At home I can, but I don't know about here...at home my icons are down here."
> We redirect her to the search bar and show her how to search for and open Word. We tell her it is a slow computer so it may take time to respond.
> Jane shrugs and laughs: "I have a slow computer at home."
> After the computer had been unresponsive for 2 full minutes:
> Jane laughs: "Okay..."
> Word opens after six minutes.

Although Jane was one of our more experienced computer users, having a computer at home that she was at least moderately comfortable using and being comfortable with skills such as spell check, she was still not confident in her ability to perform the same actions she could do at home on a computer in another setting. After waiting six minutes for Word to open, we found, once again, that poor infrastructure can easily result in and reinforce low self-efficacy. In six minutes of waiting, there is plenty of time to foster thoughts of self-doubt and desires to try to troubleshoot the issue, despite the knowledge that the action one completed was correct to accomplish the desired outcome. Aside from issues with self-efficacy, this experience can create negative impressions of computer use, once again associating it with long, frustrating wait times to complete simple tasks. Jane seemed surprised by this excessive wait time, indicating that her computer at home likely responds much more quickly, despite her admission that it is slow. This difference in performance of computers in the same area, or even the same computer at different times, supports findings of prior work that reliability and consistency is a significant issue in areas with poor infrastructure [6, 18, 35, 36, 43].

4.3.3 Vignette 7 - Gordon. During Gordon's session, the computer performed relatively well, as the network was operating at a high speed. After attempting to submit his 10 minute long story recording, the network became overloaded, the system failed, and we had to rely on our backup recordings on the digital recorders we had brought. The network was unusable for the rest of the day, which seemed to coincide with trying to upload longer audio clips. While we were waiting for his story to upload, we talked about his experiences using computers at home and generally outside of the setting of this research:

> Gordon: "I've been trying for hours to get on Ebay and I've come to the conclusion that me working on a computer, trying to do something serious, is right up there with

> going to the dentist...All this computer stuff is great, it's the trend, it's where things are going, but I'm just not [suited] for it as much as I'd like to be."

After the slowness and frustration we observed from participants on the previous day, as described in Vignettes 5 and 6, Gordon's analogy of comparing computer use to the pain and discomfort of a dental appointment felt apt. We also noticed that Gordon self-blamed, similar to the behavior and language we heard from Sharon in her session with us. Because Gordon's computer usage has occurred in an environment where the infrastructure creates such a negative experience, he generalizes this negative experience to all computer use. He also assumes that the fault is with himself, rather than with the conditions of use in his area, claiming that *he* "is not [suited] for it." When rural users experience technology in such a drastically different way than non-rural users but do not have the comparative experience of using fast, new, highly functional technology, they come to conclusions that the fault lies with themselves. After all, as Gordon notes, he has followed the rise of computing over the past several decades and believes that computers are "great, the trend, where things are going." However, he has no way of rationalizing why his experience of use is so poor if other people see computer use so positively, unless the fault is with himself.

5 DISCUSSION AND IMPLICATIONS FOR DESIGN

5.1 Poor Digital Access Transforms the Experience of Technology Use

5.1.1 Slow, Unreliable Technology Reinforces Low Self-Efficacy. Beyond the obvious frustration that a slow connection causes, the significant speed limitations we observed hold significant implications regarding user experience when considered through prior work in the field of HCI that has evaluated time and rhythm more abstractly as facets of user experience [13, 32]. For example, considering time as a commodity [32], what does the extreme slowness and required wait time of technology in our rural settings imply about the value of rural users' time? Considering rhythm in the context of our work - completing basic computer tasks, such as web browsing, form submission, opening apps, etc., has a natural rhythm to it when operating on a high-speed broadband connection. This rhythm is disrupted when the network or device is too slow and leads to a very unpleasant experience. If rhythms can only be identified by humans if they happen at intervals of less than 6 seconds [13], then the element of rhythm was often lost completely as individual actions, like button clicks, took longer than 6 seconds to register on the slow network and devices we were using. Therefore, the experience of using technology at our research site is not just a slowed down, degraded version of the user experience one has on a faster network, it is a different experience altogether. This transformed experience lacks elements of rhythm that a user in a high-speed environment considers to be a natural part of the experience of using technology.

We observed that this transformed experience of use can reinforce low self-efficacy as users attribute their poor experience to personal shortcomings, rather than failures of the technology. Prior work has highlighted technology self-efficacy and access to reliable technology as two different facets of users' experience with technology that align with, or are impacted by, users' socio-economic status [30]. In our experience, these facets reinforce one another, becoming so codependent that they can be difficult to evaluate separately. Because of poor network reliability and slow, outdated devices, the system often acted in ways that were unexpected to the user. For example, after clicking the *record* button in the voice recorder interface, the button took several seconds to register the mouse-click. Before the button would visually indicate that it had indeed registered the click, the user would then click the button again, thinking that it had not registered the click. The button would then process both clicks, leading it to start and then stop recording again. Although the users actually did act intuitively, the computer and network slowness led to an undesired result. Because of users' low technology self-efficacy, as hypothesized by Hu et

al. [30], they assumed that this undesired result was their fault, reinforcing their understandings of themselves as poor computer users and of computers as mysterious and unreliable devices. Because of the highly intertwined nature of technology reliability and self-efficacy, we believe that design considerations to remediate challenges related to these facets must consider these facets together, rather than trying to resolve them independently.

5.1.2 Effective Learning is Dependent on High-Quality Technology. The transformed experience of using technology under conditions of poor technical access (e.g., slow network, old computers) contributes to and reinforces barriers to digital literacy. This goes beyond the concept of effective use of technology, which implies some level of digital literacy and familiarity with technology. We suggest that the combination of poor access and low self-efficacy is highly detrimental to effective learning of technical skills. We observed that participants encountered barriers to learning digital literacy skills for no fault of their own, but because the unreliable nature of the technology they were using did not produce consistent results from which they could establish patterns that would lead to knowledge and understanding of computer use. For example, in Vignette 5, Sharon attempted to troubleshoot the first issue she encountered on her own before the researchers intervened to help. In attempting to resolve this first issue, Sharon took an action that would have been effective on a high-speed computer. However, it caused additional problems due to the excessive slowness of the computer and network she was using. Attempting to self-correct and troubleshoot issues is a key component of developing digital literacy and learning computer skills. However, the unreliability of exceedingly slow technology can punish troubleshooting attempts and actually discourage users from trying to learn. The second time Sharon encountered an issue, she requested help from the researchers rather than attempting to resolve the issue on her own. We can posit from this chain of events that Sharon's self-efficacy was reduced after her first troubleshooting attempt, leading her to avoid this important learning behavior, and instead depend on expert assistance when encountering issues. This is counter-productive to the development of digital literacy skills, but it is a consequence of attempting to learn on prohibitively slow and unreliable technology, which can be the only kind of technology available in rural areas.

5.2 Designing for / Deploying on Low-Speed Technology

One aspect of design that became apparent to us was that normal design choices and conventions were incompatible with the slow and unreliable network we encountered. We did not fully realize the impact of the slow network on how inexperienced users would use the system. For example, when the network went down or was busy, likely due to the 10 minute long story we attempted to upload, that story and all others that were recorded after it were not successfully uploaded to the cloud database we had linked to our system. This is why we ended up relying on our backup digital recorders for most of the stories recorded on our second day running this study. We recognize that we could have avoided these challenges by reducing, or eliminating, network dependent factors of the system we developed. However, we want to note that the poor network speeds are an ongoing reality for our participants. Due to expectations of widespread high-speed internet found in the non-rural United States, most popular websites rely heavily on multi-media elements. While our own research may have had different outcomes had we developed a tool with less network-reliance, this reality of poor speed and consequences of low-efficacy and poor learning conditions remain. With that said, we do recommend that researchers conducting work in rural areas, particularly in rural Appalachia where high-speed internet is even less accessible, thoroughly investigate the network conditions at proposed study sites to avoid the design shortcomings we have made. Additionally, researchers designing digital literacy tools or designing computer-based tools of any kind for low-speed environments may wish to avoid high-bandwidth multi-media elements such as audio or

video upload. We have also found some workarounds since conducting this study, and have modified our tools to be more flexible when speeds are unreliable. For example, the story recording website now saves a copy of the audio file and meta-data recorded in the form locally to the computer in case the internet speed is poor. This file will upload to the server when network speeds increase by using scripts and a Dropbox folder. We recommend that researchers preemptively employ backup options like this when deploying potentially network-intensive systems in low-speed environments.

In Vignette 6, we described a scenario we observed where Microsoft Word took 6 minutes to open. We expect the reason Word opened so slowly is because it had to make network calls to run the plugin we installed to import recorded story sound clips and transcriptions. Opening Word on the same computers used for this study on our home networks while testing was not noticeably slow. This was also true of booting up the computer and other standard, critical operations. Another tangential example, is that after doing a series of updates to the operating system a default setting was changed on how the browser rendered web pages. The change was to use the 3D card (our computer had a very modest one), to do the rendering, and this change meant that the browser was unusably slow, even on high speed connections. This setting was buried deep in the browser settings, and there is no way that our participants would be able to remedy the situation and they would have assumed something was broken. These experiences highlight software changes intended for high-speed network connections or advanced hardware that cause poor experiences on slow connections or using modest hardware. This has also been noted in prior rural HCI work [35]. Based on these experiences, we also recommend, particularly to HCI practitioners developing tools for widespread deployment and use, to consider a variety of network and hardware conditions when pushing new features. If new features cannot be developed to be compatible with users on lower-speed networks or lower-tech devices, at the very least, options to disable these features should be clearly presented to users.

6 CONCLUSION

In this work, we designed and deployed a system to teach digital literacy skills through digital storytelling in a rural Appalachian community. We found digital storytelling to be highly culturally resonant with the community. This was beneficial in encouraging computer use among a community with relatively low technology self-efficacy. Participants learned computer skills through their use of the system, often without even realizing it. Despite having taken significant measures to accommodate slow and unreliable network conditions at our study site, the network still posed significant challenges to participants' use of the system. In our observations of participants' use of the system, we realized that rural users' experience with computers is not just a degraded version of non-rural users' computer use, but a different experience entirely. To rural users, computers are unreliable, unintuitive and frustrating. When a person learns to use technology using outdated devices and slow, unreliable networks, the technology will often act unexpectedly to completely rational behaviors of use. This prevents users from forming a mental model of what expected computer behavior looks like and promotes low self-efficacy. These observations form a new theory of differentiated use, attitudes, and perceptions of technology in rural areas that we hope will continue to inform future work in rural HCI.

REFERENCES

[1] M. Cecília C. Baranauskas. 2014. Social awareness in HCI. *Interactions* 21, 4 (July 2014), 66–69. https://doi.org/10.1145/2621933

[2] ALLEN BATTEAU. 1979. Appalachia and the Concept of Culture: A Theory of Shared Misunderstandings. *Appalachian Journal* 7, 1/2 (1979), 9–31. http://www.jstor.org/stable/40932719 Publisher: Appalachian Journal & Appalachian State University.

[3] Amy M. Bauer, Sarah Hodsdon, Suzanne Hunter, Youlim Choi, Jared Bechtel, and John C. Fortney. 2017. Lessons from the deployment of the SPIRIT app to support collaborative care for rural patients with complex psychiatric conditions. In *Proceedings of the 2017 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2017 ACM International Symposium on Wearable Computers*. ACM, Maui Hawaii, 772–780. https://doi.org/10.1145/3123024.3125610

[4] Nicola J. Bidwell, Thomas Reitmaier, Gary Marsden, and Susan Hansen. 2010. Designing with mobile digital storytelling in rural Africa. In *Proceedings of the 28th international conference on Human factors in computing systems - CHI '10*. ACM Press, Atlanta, Georgia, USA, 1593. https://doi.org/10.1145/1753326.1753564

[5] David Browning, Nicola J Bidwell, Dianna Hardy, and P-M Standley. 2008. Rural encounters: cultural translations through video. In *Proceedings of the 20th Australasian Conference on Computer-Human Interaction Designing for Habitus and Habitat - OZCHI '08*. ACM Press, Cairns, Australia, 148. https://doi.org/10.1145/1517744.1517790

[6] Jenna Burrell. 2018. Thinking relationally about digital inequality in rural regions of the U.S. *First Monday* (June 2018). https://doi.org/10.5210/fm.v23i6.8376

[7] Banny S. K. Chan, Daniel Churchill, and Thomas K. F. Chiu. 2017. Digital Literacy Learning In Higher Education Through Digital Storytelling Approach. *Journal of International Education Research (JIER)* 13, 1 (May 2017), 1–16. https://doi.org/10.19030/jier.v13i1.9907

[8] Jay Chen, Lakshminarayanan Subramanian, and Kentaro Toyama. 2009. Web search and browsing behavior under poor connectivity. In *CHI '09 Extended Abstracts on Human Factors in Computing Systems*. ACM, Boston MA USA, 3473–3478. https://doi.org/10.1145/1520340.1520505

[9] Marshini Chetty, David Haslem, Andrew Baird, Ugochi Ofoha, Bethany Sumner, and Rebecca Grinter. 2011. Why is my internet slow?: making network speeds visible. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, Vancouver BC Canada, 1889–1898. https://doi.org/10.1145/1978942.1979217

[10] Natalia Churchill, Hong Kong, Lim Cher Ping, Grace Oakley, and Daniel Churchill. 2008. DIGITAL STORYTELLING AND DIGITAL LITERACY LEARNING. (2008), 13.

[11] Lane W. Clarke. 2020. Walk a Day in My Shoes: Cultivating Cross-Cultural Understanding Through Digital Literacy. *The Reading Teacher* 73, 5 (2020), 662–665. https://doi.org/10.1002/trtr.1890 _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1002/trtr.1890.

[12] Appalachian Regional Commission. [n.d.]. About the Appalachian Region. https://www.arc.gov/about-the-appalachian-region/

[13] Brigid M. Costello. 2020. Paying attention to rhythm in HCI: Some thoughts on methods. In *32nd Australian Conference on Human-Computer Interaction*. ACM, Sydney NSW Australia, 471–480. https://doi.org/10.1145/3441000.3441005

[14] Mark Davies, Alan Chamberlain, and Andy Crabtree. 2013. Issues and Understandings for Rural HCI Systems Development: Agile Approaches "In the Wild". In *HCI International 2013 - Posters' Extended Abstracts*, Constantine Stephanidis (Ed.). Vol. 373. Springer Berlin Heidelberg, Berlin, Heidelberg, 22–26. https://doi.org/10.1007/978-3-642-39473-7_5 Series Title: Communications in Computer and Information Science.

[15] Sharon A. Denham. 2016. Does a Culture of Appalachia Truly Exist? *Journal of Transcultural Nursing* 27, 2 (March 2016), 94–102. https://doi.org/10.1177/1043659615579712 Publisher: SAGE Publications Inc.

[16] Allison Druin (Ed.). 2009. *Mobile technology for children: designing for interaction and learning*. Elsevier/Morgan Kaufmann Publishers, Amsterdam ; Boston. OCLC: ocn299240550.

[17] Marisa Elena Duarte, Morgan Vigil-Hayes, Ellen Zegura, Elizabeth Belding, Ivone Masara, and Jennifer Case Nevarez. 2021. As a Squash Plant Grows: Social Textures of Sparse Internet Connectivity in Rural and Tribal Communities. *ACM Transactions on Computer-Human Interaction* 28, 3 (July 2021), 1–16. https://doi.org/10.1145/3453862

[18] Bekithemba Dube. 2020. Rural online learning in the context of COVID 19 in South Africa: Evoking an inclusive education approach. *Multidisciplinary Journal of Educational Research* 10, 2 (June 2020), 135. https://doi.org/10.17583/remie.2020.5607

[19] Constance Elam. 2002. Culture, Poverty and Education in Appalachian Kentucky. (2002), 5.

[20] Eric Gilbert, Karrie Karahalios, and Christian Sandvig. 2008. The network in the garden: an empirical analysis of social media in rural life. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '08)*. Association for Computing Machinery, New York, NY, USA, 1603–1612. https://doi.org/10.1145/1357054.1357304

[21] Chris Greenhalgh, Alan Chamberlain, Mark Davies, Kevin Glover, Stela Valchovska, and Andy Crabtree. 2014. Displaying Locality: Connecting with Customers and Visitors In-Situ via their Mobile Devices. In *Proceedings of The International Symposium on Pervasive Displays*. ACM, Copenhagen Denmark, 62–67. https://doi.org/10.1145/2611009.2611021

[22] John Christopher Haddox. 2018. Impact of Design on Patient Participation in Healthcare in a Rural Health Clinic in Appalachia: A Qualitative Pilot Study. *HERD: Health Environments Research & Design Journal* 11, 1 (Jan. 2018), 31–39. https://doi.org/10.1177/1937586717696701 Publisher: SAGE Publications Inc.

[23] Jean Hardy, Dharma Dailey, Susan Wyche, and Norman Makoto Su. 2018. Rural Computing: Beyond Access and Infrastructure. In *Companion of the 2018 ACM Conference on Computer Supported Cooperative Work and Social Computing*.

ACM, Jersey City NJ USA, 463–470. https://doi.org/10.1145/3272973.3273008
[24] Jean Hardy, Chanda Phelan, Morgan Vigil-Hayes, Norman Makoto Su, Susan Wyche, and Phoebe Sengers. 2019. Designing from the rural. *Interactions* 26, 4 (June 2019), 37–41. https://doi.org/10.1145/3328487
[25] Jean Hardy, Susan Wyche, and Tiffany Veinot. 2019. Rural HCI Research: Definitions, Distinctions, Methods, and Opportunities. *Proceedings of the ACM on Human-Computer Interaction* 3, CSCW (Nov. 2019), 1–33. https://doi.org/10.1145/3359298
[26] Christopher G. Harris and Janet C. Achora. 2018. Designing ICT for Agriculture (ICT4A) Innovations for Smallholder Farmers: The Case of Uganda. In *Proceedings of the XIX International Conference on Human Computer Interaction*. ACM, Palma Spain, 1–9. https://doi.org/10.1145/3233824.3233830
[27] Amanda Hayes. 2017. Place, Pedagogy, and Literacy in Appalachia. *English Education* (2017), 19.
[28] Thomas Hertz and Andrew Silva. 2020. Rurality and Income Inequality in the United States, 1975–2015. *Rural Sociology* 85, 2 (2020), 436–467. https://doi.org/10.1111/ruso.12295 _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/ruso.12295.
[29] Rae Hodge. 2021. Here's the place that will make or break Biden's broadband plan. https://www.cnet.com/features/heres-the-place-that-will-make-or-break-bidens-20-billion-broadband-plan/
[30] Catherine Hu, Christopher Perdriau, Christopher Mendez, Caroline Gao, Abrar Fallatah, and Margaret Burnett. [n.d.]. Toward a Socioeconomic-Aware HCI: Five Facets. ([n. d.]), 37.
[31] Naveena Karusala, Aditya Vishwanath, Arkadeep Kumar, Aman Mangal, and Neha Kumar. 2017. Care as a Resource in Underserved Learning Environments. *Proceedings of the ACM on Human-Computer Interaction* 1, CSCW (Dec. 2017), 104:1–104:22. https://doi.org/10.1145/3134739
[32] Siân Lindley, Robert Corish, Elsa Kosmack Vaara, Pedro Ferreira, and Vygandas Simbelis. 2013. Changing perspectives of time in HCI. In *CHI '13 Extended Abstracts on Human Factors in Computing Systems on - CHI EA '13*. ACM Press, Paris, France, 3211. https://doi.org/10.1145/2468356.2479649
[33] Norman Makoto Su, Jean Hardy, Morgan Vigil-Hayes, Tiffany Veinot, and Rob Comber. 2021. Introduction: Performing Rurality with Computing. *ACM Transactions on Computer-Human Interaction* 28, 3 (July 2021), 1–13. https://doi.org/10.1145/3461832
[34] A Maunder, G Marsden, and W D Tucker. [n.d.]. Evaluating the relevance of the 'Real Access' criteria as a framework for rural HCI research. ([n. d.]), 4.
[35] Roberta M Melvin and Andrea Bunt. 2012. Designed for work, but not from here: rural and remote perspectives on networked technology. (2012), 10.
[36] Roberta M. Melvin, Andrea Bunt, Erick Oduor, and Carman Neustaedter. 2015. The Effect of Signal Expense and Dependability on Family Communication in Rural and Northern Canada. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. ACM, Seoul Republic of Korea, 717–726. https://doi.org/10.1145/2702123.2702301
[37] Jerry W. Morris. 1979. The Aesthetics of Rural Appalachia's Poverty Culture. *Appalachian Heritage* 7, 1 (1979), 25–31. https://doi.org/10.1353/aph.1979.0035
[38] Hannele Niemi, Vilhelmiina Harju, Marianna Vivitsou, Kirsi Viitanen, Jari Multisilta, and Anne Kuokkanen. 2014. Digital Storytelling for 21st-Century Skills in Virtual Learning Environments. *Creative Education* 05, 09 (2014), 657–671. https://doi.org/10.4236/ce.2014.59078
[39] Kelvin Pollard and Linda A Jacobsen. [n.d.]. THE APPALACHIAN REGION: A DATA OVERVIEW FROM THE 2015-2019 AMERICAN COMMUNITY SURVEY Chartbook. ([n. d.]), 181.
[40] Chaundel Presley. 2013. Cultural Awareness: Enhancing Clinical Experiences in Rural Appalachia. *Nurse Educator* 38, 5 (2013), 223–226. https://doi.org/10.1097/NNE.0b013e3182a0e556
[41] María Graciela Badilla Quintana and Eduardo Parra Zambrano. 2014. E-mentoring: The effects on pedagogical training of rural teachers with complex geographical accesses. *Computers in Human Behavior* 30 (Jan. 2014), 629–636. https://doi.org/10.1016/j.chb.2013.07.042
[42] Brian Real and R Norman Rose. 2017. Rural Libraries in the United States. (2017), 19.
[43] Fiona Redhead, Stephen Snow, Dhaval Vyas, Owen Bawden, Ray Russell, Tristan Perez, and Margot Brereton. 2015. Bringing the Farmer Perspective to Agricultural Robots. In *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems*. ACM, Seoul Republic of Korea, 1067–1072. https://doi.org/10.1145/2702613.2732894
[44] Jennifer L. Rice and Brian J. Burke. 2018. Building More Inclusive Solidarities for Socio-Environmental Change: Lessons in Resistance from Southern Appalachia. *Antipode* 50, 1 (2018), 212–232. https://doi.org/10.1111/anti.12336 _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/anti.12336.
[45] Bernard R Robin. 2006. The Educational Uses of Digital Storytelling. (2006), 8.
[46] Cara Robinson. 2015. An Exploration of Poverty in Central Appalachia: Questions of Culture, Industry, and Technology. *KOME* 3, 2 (Dec. 2015), 75–89. https://doi.org/10.17646/KOME.2015.26

[47] Sarah Robinson, Nicola J. Bidwell, Roberto Cibin, Conor Linehan, Laura Maye, John Mccarthy, Nadia Pantidi, and Maurizio Teli. 2021. Rural Islandness as a Lens for (Rural) HCI. *ACM Transactions on Computer-Human Interaction* 28, 3 (July 2021), 1–32. https://doi.org/10.1145/3443704

[48] Alaa Sadik. 2008. Digital storytelling: a meaningful technology-integrated approach for engaged student learning. *Educational Technology Research and Development* 56, 4 (Aug. 2008), 487–506. https://doi.org/10.1007/s11423-008-9091-8

[49] Max O. Stephenson and A. Scott Tate (Eds.). 2015. *Arts and community change: exploring cultural development policies, practices and dilemmas.* Routledge, New York.

[50] Zihad Tarafdar. [n.d.]. Software Development for a Secure Telemedicine System for Slow Internet Connectivity. ([n. d.]), 206.

[51] Brian C. Thiede, Jaclyn L. W. Butler, David L. Brown, and Leif Jensen. 2020. Income Inequality across the Rural-Urban Continuum in the United States, 1970–2016*. *Rural Sociology* 85, 4 (2020), 899–937. https://doi.org/10.1111/ruso.12354 _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/ruso.12354.

[52] N. Tolia, D.G. Andersen, and M. Satyanarayanan. 2006. Quantifying interactive user experience on thin clients. *Computer* 39, 3 (March 2006), 46–52. https://doi.org/10.1109/MC.2006.101 Conference Name: Computer.

[53] Natalie Underberg-Goode. 2017. Digital Storytelling for Heritage across Media. *Collections* 13, 2 (June 2017), 103–114. https://doi.org/10.1177/155019061701300205 Publisher: SAGE Publications Inc.

[54] Lynne Masel Walters and Sam von Gillern. 2018. We Learn in the Form of Stories: How Digital Storytelling Supports Critical Digital Literacy for Pre-Service Teachers. *International Journal of Digital Literacy and Digital Competence* 9, 3 (July 2018), 12–26. https://doi.org/10.4018/IJDLDC.2018070102

[55] Susan P. Wyche. 2011. Designing for everyday interactions in HCI4D. *Interactions* 18, 2 (March 2011), 52–56. https://doi.org/10.1145/1925820.1925832

[56] Susan P. Wyche, Thomas N. Smyth, Marshini Chetty, Paul M. Aoki, and Rebecca E. Grinter. 2010. Deliberate interactions: characterizing technology use in Nairobi, Kenya. In *Proceedings of the 28th international conference on Human factors in computing systems - CHI '10.* ACM Press, Atlanta, Georgia, USA, 2593. https://doi.org/10.1145/1753326.1753719

[57] Mun Y Yi and Yujong Hwang. 2003. Predicting the use of web-based information systems: self-efficacy, enjoyment, learning goal orientation, and the technology acceptance model. *International Journal of Human-Computer Studies* 59, 4 (Oct. 2003), 431–449. https://doi.org/10.1016/S1071-5819(03)00114-9

Received January 2022