

# Engaging Lived and Virtual Realities

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## ABSTRACT

We examined the integration of VR into informal and less-structured learning environments in Atlanta (USA) and Mumbai (India) through a process of co-design, co-creation, and co-learning with students and teachers where students learned to use VR to engage with their economic, social, and cultural realities. Using qualitative methods, we engaged students and teachers at both sites in VR content creation activities; through these activities, we attempt to uncover a deeper understanding of the challenges and opportunities of introducing low-cost mobile VR for content generation, consumption, and sharing in underserved learning contexts. We also motivate future work that looks at integrating VR in new contexts, using flexible methods, across borders. The larger vision of our research is to advance us towards greater accessibility and inclusivity of VR across diverse learning environments.

## CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**.

## KEYWORDS

VR; India; USA; Classrooms; HCI4D

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## 1 INTRODUCTION

The collective vision, or *imaginaire*, that industry actors, policy makers, researchers, and the general public share of the future of a society plays a key role in promoting technological innovations and legitimizing particular modes of technologies over others [30, 49]. In the case of Virtual Reality (VR), the industry’s efforts to create products that are tractable and lower-cost than before symbolize a vision for a society where VR is accessible to everyone. Not only might VR be used to enhance users’ experience of realities outside their own, they might also learn to *create* them without significant effort. Such visions, scholars such as Flichy have argued [30], are important to bring to scrutiny, because they influence which forms and uses of technology are prioritized over others. The public typically enters the negotiation of a common vision at later stages of development, thus missing out on opportunities to influence how these technologies might meaningfully impact their daily lives.

Our research explores a potential meeting point between the above *imaginaire* for VR’s future and everyday contexts such as classrooms. Situating ourselves in underserved learning environments, we study how *low-cost, smartphone-driven, immersive, 360-degree VR* might be ‘perceived to bring value’ to such settings. That is, we intend to highlight what our participants valued in VR and how they wished to bring out that value, connecting values and behavior [35]. We draw on data collected through fieldwork at a summer camp in Atlanta, USA, and an after-school center in Mumbai, India, both of which catered to children from underserved, socio-economically disadvantaged communities. Through VR content creation projects centered around social justice topics, we used co-design, interviews, and observations to examine diverse stakeholders’ assumptions and beliefs around VR, and to speculate and reflect on the capacities, limitations, and applications of this technology for day-to-day use. Studying underserved contexts in the Global North and South allowed us to also reflect on VR’s future in an increasingly globalized, transnational world. Particularly, we highlight how VR’s affordances might translate across cultures and geographies.

In this paper, we begin by situating our work in related literature on the affordances of low-cost VR, making VR usable for everyday contexts, as well as research that has examined user engagement with the integration of new technologies into classrooms. Our methodology section provides an in-depth description of our study and its goals, explaining how and why we engaged in co-design with teachers, students, and other stakeholders in Atlanta and Mumbai, to introduce VR through storytelling. Our findings convey the perceptions of the different stakeholders at both sites, as they explored new experiences with VR *in the wild*. In our discussion, we outline reflections and takeaways for (1) introducing VR into new types of contexts—beyond classrooms like ours, (2) engaging in co-design—its opportunities and challenges when interfacing with new technologies, and (3) transferring emerging technologies such as VR between the Global North to the South, especially in geographies where the much recognized “digital divide” [20, 48] might be narrowing.

Our research is aimed at motivating a large and growing community of VR enthusiasts who are actively exploring diverse mechanisms and environments for engaging with this medium, and for a wide array of objectives [17, 25, 34, 38, 84]. To this end, our research questions are:

- (1) How might underserved learning environments engage with low-cost 360-degree VR in ways that align with stakeholders’ priorities and values—their lived realities?
- (2) What are the social and technical infrastructural challenges confronting the integration of 360-degree VR in classrooms across diverse under-resourced contexts?

As the industry pushes for VR technologies and experiences to become increasingly mainstream [31, 42], the larger vision of our research is to enable the general public to engage with and explore VR’s affordances on their own terms.

## 2 RELATED WORK

We now describe how the increasing affordability of immersive VR, much like past revolutionary communication technologies, allows us to explore its use in everyday contexts. We then detail how our research connects with prior work on introducing new technologies to classroom settings, and leveraging content creation as an instructional tool. This allows us to imagine a future where VR might be used beyond elite contexts.

In its short history, VR has generally been viewed by the public as a wondrous, unusual experience, different from other forms of communication by virtue of its surreal immersiveness and need for unique devices [13]. This perception is unsurprising considering VR technologies are relatively new and research and industry actors have initially worked with expensive prototypes. The research sphere has largely

studied the affordances of VR (*e.g.*, [1, 52, 73, 78]) or applied VR to create immersive experiences (*e.g.*, [14, 18, 63]), but both subdomains tend to focus on expensive head-mounted displays [6, 12, 14, 15, 33, 34, 63], multi-person virtual rooms [18, 23, 72, 73], or entirely new prototypes of VR-centric technology [7, 12]. Commercial availability of VR technology has followed the same trend with a range of high-end products like HTC Vive, Oculus Rift, Oculus Go, and Playstation VR, and on the lower end, Samsung Gear and Google Daydream [26, 36, 58, 75, 79]. Even considering VR beyond personal use, individuals are most likely to encounter VR in contained settings, such as museums, libraries, or theme parks [47].

More recently, there has been a noticeable trend towards making VR usable for everyday contexts. This is signaled by growing availability of low-cost and portable 360-degree cameras and VR headsets that work with smartphones, a trend that began with Google Cardboard’s release in 2014 [26, 80]. Only a handful of studies thus far have engaged with the vision of low-cost and pervasive VR, however, namely studies of Google Cardboard and Google Expeditions in learning environments in rural and urban India [67, 81] and the United Kingdom [54, 62]. These studies highlight certain affordances of VR for learning, such as supporting knowledge of spatial awareness and analytical inquiry [54, 62, 67, 81]. Though industry actors have moved to propose a vision of more accessible VR, research is following at a slower pace, perpetuating the lack of understanding of how users can and do utilize VR in everyday experiences. We build off of the value of VR in learning environments to study the potential futures VR might have in diverse, everyday contexts.

By situating our research in diverse and underserved learning contexts, we follow the tradition of HCI work that studies the integration or adaptation of new technology and its infrastructure into such environments. In these studies, we pay specific attention to how users engaged with and responded to the integration of a new intervention. We extend work such as studies of how personal computers or laptops can be adapted to low-resource classrooms [2, 19, 60], the extensive literature on introducing technology like iPads or augmented reality to learning environments (*e.g.*, [11, 21, 24, 56, 64, 68]), or work on adding communications technologies to classrooms to enable distance learning [4, 22, 65]. The few studies on the integration of VR in the wild have been conducted in the context of museums [17, 28, 55] and medical therapy [40]. Carrozzino and Bergamasco suggest considering usability, cost, and space requirements when using VR in museums [17]. Rizzo and Kim theoretically analyze the strengths, weaknesses, opportunities, and threats related to VR integration in medical therapy [40]. We extend this work by introducing VR in the wild and considering transferability across contexts. We also consider how, unlike prior work on integration of VR, social infrastructure such as methods of co-design

|            | Atlanta |         | Mumbai  |         |
|------------|---------|---------|---------|---------|
|            | Female  | Male    | Female  | Male    |
| Teachers   | T1–T6   | T7–T8   | T9      | T10     |
| Volunteers | V1–V4   | V5–V8   | V9–V10  | V11–V12 |
| Students   | S1–S34  | S35–S60 | S61–S70 | S71–S82 |

**Table 1: Participants in Atlanta & Mumbai**

[76] and collective meaning-making of technology [9, 57] can support technology integration.

To study the integration of VR in the classroom, we draw upon the vision for VR in learning environments from prior work. Vishwanath et al. discuss how integrating Google Expeditions into a learning center in Mumbai resulted in students and teachers imagining further uses, particularly with creating new VR content [81]. We sought to explore how Vishwanath et al.'s proposed vision of VR as a content creation technology might take shape, also shaped by the value attributed to digital storytelling for developing students' literacies in technology, art, and communication and developing a sense of identity and agency [8, 59, 69]. Exploring immersive VR content creation is timely, as industry has only recently started to support low-cost content creation, while there has been very little research in this area. Early studies presented highly involved set-ups to enable 3D drawings, animations, and note-taking [10, 45, 66]. More recent work, though it has somewhat streamlined content creation, excludes immersive VR, focusing on creating computer games [70], Augmented Reality (AR) components [39, 44, 77], or non-immersive virtual environments [83]. Industry actors like Snapchat, Facebook, and Apple have made greater strides in this space, streamlining smartphone-based content creation with AR. Facebook, Google, Roundme, and a number of other companies have made 360-image capturing, rendering, and hosting more accessible through free or low-cost platforms, cameras, and smartphone-compatible software. However, there is a gap in research on how these tools are being (or could be) used and adopted, including as instructional tools—the gap that our work aims to address.

### 3 METHODOLOGY

We now describe our field sites and participants, the co-design process we undertook, and data analysis.

#### Field Sites, Participants, and Transferability

Our field sites included a summer camp organized by a charter school in Atlanta and an after-school center run by a non-profit in Mumbai. Both served ninth grade students (13-16 years) from socioeconomically disadvantaged backgrounds.

The students in Atlanta (S1-S60) were African-American (56) or Hispanic (4). There were 6 first generation high schoolers, 24 potentially first generation college students, and many raised in a single parent household. They came from lower middle class homes in a neighborhood with a history of high crime rates, which has significantly improved in recent years as a result of many public initiatives and investments [5].

The after-school center in Mumbai was located in a suburb densely inhabited by migrant workers, earning USD 8-15 a day. Students spoke mainly Hindi and Marathi, and had intermediate English proficiency. Classes took place in the morning (/afternoon) to cater to students attending public schools in the afternoon (/morning). We chose both these centers as study sites because the teachers/staff were keen to integrate new technologies (such as VR), and afforded the opportunity to work with a socioeconomically and culturally diverse group of students.

Of the 82 students, 38 (of 60) students in Atlanta and 16 (of 22) in Mumbai had no prior exposure to VR. This offered us some diversity in students' prior VR experiences. We also identified 22 support staff participants in Atlanta and Mumbai (see Table 1). These included eight teachers (T1-T8) and eight volunteers (V1-V8) in Atlanta, and two teachers (T9-T10) and four volunteers (V9-V12) in Mumbai. Volunteers were unpaid instructors, interns, or assistants at the two schools. The teachers selected the volunteers at both sites; these included older students, college summer interns, or school/center staff.

In selecting our sites, we were keen to better understand the challenges introduced on account of transferability [29]. This raises particularly compelling questions when we recognize that the requisite infrastructure for engagement with low-cost VR existed at both settings, and the technology was seen to carry comparable novelty in both. We chose a site in the Global North and one in the Global South so that we could assess how VR would be received and integrated in starkly different contexts, but with comparable levels of exposure to the technology. The camp was a more organized set-up than the school in Mumbai, and therefore had more students. Cultural backgrounds were also naturally different. However, research subjects at both sites came from socioeconomically weaker sections, were keen on creating their own VR content, and had comparable exposure and literacies to emerging technologies. Our findings describe how these differences and similarities played a role in how students and teachers interacted with VR and made sense of it.

#### Co-Design with Teachers and Students

We chose to scaffold the learning, tinkering, and use of VR through the five stages described below to gently integrate this medium with existing mental models and workflows of participants. We draw inspiration from the co-design [76]

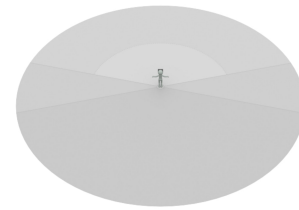
method and from prior studies that have used this method [43, 74] to develop these five stages. Stage 0 took a week at both sites (with teachers and volunteers). Stages 1-4 took place over two weeks at both sites with the students. All data collection was approved by the Institutional Review Board (IRB), with permissions from authorities at both sites.

*Stage 1: Storytelling and Theme Selection.* We worked with the supporting staff at both sites to understand their perceptions, concerns, and priorities in aligning VR with learning outcomes. In this stage, we introduced all teachers/volunteers to the 360-degree camera [80] (using Android smartphones) and the process of generating, uploading, consuming, and sharing content. Through this co-design stage (motivated by Vishwanath et al. [81]), our teachers identified storytelling as an exercise that would enable students at both sites to use VR for engaging meaningfully with their surroundings. We brainstormed with teachers at both places and what connected with them most was this idea of content generation to *build social awareness*. While the theme of “*hunger and homelessness*” was selected for our Atlanta site, Mumbai participants selected “*respect*” (towards a person, group, or place)<sup>1</sup>. Our co-design process meant that we let the teachers make the decision on how they wanted students to engage with these topics. Teachers in Atlanta chose to focus on the city’s homelessness crisis, while in Mumbai, teachers wanted students to foster respect towards their surroundings more broadly, and offered them the creative freedom to choose their demographic. In Atlanta, students used VR for storytelling about communities they were not part of, while those in Mumbai had the freedom to engage with any community. Once the themes had been identified for both sets of students by the teachers via the co-design stage, we worked with teachers and volunteers to devise the next four stages, outlined below.

*Stage 2: Learning VR.* We took a day at both sites to explore the mental models students had around the use of VR, and map their current understanding of this technology to the use of the cameras for filming. After the students had learned how to use the 360-degree cameras and seen multiple demos, we presented them with the timeline for our study, and conducted a team formation exercise.

*Stage 3: Brainstorming and Storyboarding.* In this stage, which lasted four hours, students worked in their teams (15 teams in Atlanta and 6 teams in Mumbai) to (1) brainstorm ideas for their storytelling project, (2) narrow down ideas by clustering similar threads, carve out a cogent story, and storyboard their scenes, and (3) create a concrete action plan and timeline for capturing this content at different sites. We used methods inspired by cooperative inquiry, a methodology for aiding children and adults in brainstorming and prototyping

<sup>1</sup>There is, in fact, no word that directly translates to “homeless” in Hindi.



**Figure 1: This template is widely used for VR storyboarding, which is different from 2D storyboarding. It entails a stick figure in the center (the viewer) and a palette—the complete 360-degree scene.**

together [27]. This involved providing large sheets and markers for expansive note-taking, having the VR cameras available to experiment with at any time, and having the adults walk around to inquire about and facilitate the students’ progress. For storyboarding, we used the template in Figure 1—widely used for VR storyboarding [50]. We discussed the details of this template with all participants, providing them with multiple examples of it in use.

*Stage 4: Filming.* In this stage, students took 360-degree photos and visited the sites recommended to them by the teachers. Their field visits were spread across five days. In stages 3 and 4, we paid special attention to the workarounds developed by students as they learned to storyboard and film in VR. Each team made one movie; at the end of this stage, students in Atlanta had collectively filmed 15 movies and students in Mumbai had filmed 6 movies.

*Stage 5: Editing and Uploading.* This final stage lasted five hours, when we (along with the staff) taught students to create a VR movie on Roundme [71] or YouTube. The goal was to support students in compiling and sharing their final VR movies. With Roundme, students uploaded a series of 360-degree images, embedded media into the images (such as text snippets, other images, or short videos) to highlight specific sections of the 360-degree image, and linked different images to one another using portals (or doorways), thereby completing their stories. With YouTube, learners compiled their 360-degree images in iMovie/Windows Movie Maker, added a voice-over (recorded using a phone microphone), injected metadata, and uploaded the file to YouTube (which automatically rendered it in a 360-degree format). Both formats allowed the stories to be experienced in immersive VR through a cardboard viewer and smartphone.

### Data Collection and Analysis

We conducted extensive data collection at both sites, conducting interviews, verbal/written surveys, and participant observation to remain informed and able to assess participants’ reactions to the VR experience we co-designed with them.

Our data included photographs, audio recordings, field notes, survey results, and interview transcripts, which we analyzed altogether and inductively as recommended by Merriam [51], noting in particular the instances of meaning-making [9, 57]. All authors together coded the data line-by-line, and captioned lines with phrases summarizing the content, such as “*prior examples of technology use*” or “*volunteers’ perspective*”. Authors iterated on the data to come up with key representative themes, spanning the initial co-design to align VR with classroom goals, the process of learning how to use it for storytelling, students’ actual usage of the cameras, and participants’ perceptions of VR through the creation process.

### Self-Disclosure

We derive motivation from JafariNaimi’s call for research on VR to engage with lived realities [37], and found common ground with teachers on engaging with topics of social justice close to students’ contexts. Fieldwork in Atlanta was conducted by first and second authors, both of Indian origin (although the second author has lived in Atlanta for 15+ years). Fieldwork in Mumbai was conducted by the first author alone and almost entirely in Hindi, in which he has native fluency. He was also able to blend in easily because the volunteers at the Mumbai center were similar in age and ethnicity. This was harder in Atlanta, where students came from different ethnicities. Data analysis was conducted by all authors (three female and one male), who have all pursued higher education in the United States in STEM fields. They all have experience with research in India in various domains of education, mobile phone use, health, and gender, with experience in qualitative research, design, and system-building.

## 4 FINDINGS

Across both sites, and throughout our study, we found that meaning-making took on different dimensions for different participants. Below we describe these findings, first focusing on participants’ co-learning how to use cameras and storyboards. We then offer their reflections on using, working with, and storytelling via VR. We note again that by VR, we mean relatively low-cost mobile VR technology (Ricoh Theta 360-degree camera [80], Android smartphone, and cardboard viewer). Throughout our findings, we highlight differences and commonalities observed across sites.

### Co-Design with Teachers

In the first stage of co-design, our goal was to understand how the teachers perceived VR’s potential as a technology in the classroom. We found them to assign different potential meanings to VR, ranging from an interesting skill for students to have to a medium for traveling to inaccessible places. These notions were simultaneously colored by reservations about the feasibility to accommodate VR in their classrooms,

a concern that came up in both Atlanta and Mumbai. VR was perceived as a source of distraction in some cases and teachers voiced some hesitations regarding accommodating VR in their classrooms. For example, T9 in Mumbai shared prior experiences with technology where students would play games to try to avoid learning, as she had experienced with tablet applications in the past. Some teachers from Atlanta also asserted their desire to use this new technology if and only if there was a real need to do so.

Teachers also constructed different meanings around the practicality of bringing VR content creation to the classroom. T9 from Mumbai perceived VR offering meaning “*in the form of a skill, just like why we would teach PowerPoint*”. T1 from Atlanta associated VR with an “*opportunity to connect students to the world around them*”, making the content more relatable. There was also a focus on experiential learning [41] and teaching topics difficult to engage with otherwise. A teacher in Mumbai commented:

*“I would definitely love to do things with VR that are ‘space and scale’ related, i.e. taking students to spaces that they cannot necessarily access. Like the depths of the ocean, the core of the earth—these trips will give my students a big-picture idea of these macroscopic ‘space/scale’-related themes. These are themes I cannot teach my kids—they need to really experience the depth of the ocean to truly understand its scale.” (T9)*

Teachers felt it was important for students to take field trips so they could experience multiple contexts “*and say that ‘it was as if I touched this and went there’*” (T7) This approach is supported by research that has used VR and mixed reality technologies to enhance engagement and learning through embodied interactions [46, 61].

In our co-design sessions, teachers frequently referred to their prior experiences with other digital teaching aids to shape their stance on VR. This led to their asking questions on feasibility and practicality of this technology for learning, but also sparked curiosity since teachers recognized that VR would offer the ability to take new perspectives, represent space and scale, and deliver immersive experiences. The specific ways in which teachers explored this practicality of using VR were shaped by their different contexts and previous experiences. We found that although teachers in Atlanta and Mumbai were both enthusiastic about introducing VR to their students, the teachers in Atlanta seemed more pragmatic and measured in their enthusiasm—perhaps because of greater prior exposure to technologies in general and VR in particular. They questioned the *value* of using VR that went beyond its perceived affordances of engagement and highlighted the “*fact that we have to do this because VR is cool*” (T2). Teachers in Mumbai were specifically concerned

about the challenges of integrating VR due to constrained resources, specifically lack of time, and they also had reservations around students losing focus. At both sites, however, teachers were very willing to engage the students in active learning exercises [16], as evident from their feedback, and saw potential for VR to drive these exercises.

### Co-Design with Students

We highlight next how students co-designed their stories in teams through engaging in meaning making of the 360-degree cameras and the storyboarding process.

*Co-Learning to Use 360-Degree Cameras.* We first taught the volunteers how to use the VR toolkit, making sure they were prepared to orient students if they ran into problems on their first use. We then had students open and explore the cameras in the classroom. These cameras were seen as both a source of curiosity and complexity by them. The training we provided seemed inadequate to S22 after the first day: *“It just felt like... here are the cameras. Take a look at them. Figure it out. I just wish we could have had a lot more understanding. I think we currently have a very surface level understanding of what we can do.”* Teachers at both sites suggested that the training process could include a more thorough explanation of how to use the cameras. However, this did not mean that the students’ tinkering with the cameras on their own was fruitless. T9 at Mumbai described why she liked this format: *“I like the fact that you allowed the students to figure some things out on their own first. To tinker with it a little bit to see how it’s used and, in doing that, they may find ways to use it that I haven’t considered. I also liked how you introduced it to them, by giving some examples of how you’ve used it.”* This tinkering process aligns with the constructivist perspective of *‘learning by doing’*—constructing knowledge of the world through experiencing things and reflecting on those experiences [82]. There were also students in Mumbai who figured out how to use the cameras by *“asking a lot of questions about the cameras”* (S74) in the initial stages of our study. This highlights student curiosity that was supported through their interaction with the cameras.

There were students, however, who did not enjoy this process of tinkering as much; teachers expressed concern that the cost of the cameras impacted the student engagement at this stage. This fragility and cost of cameras was perceived by the teachers as well:

*“At first they were very interested. After that [they] felt like they didn’t know how to use the camera, they started getting a little more detached. So a lot of them just... didn’t feel comfortable with the camera. We kept stressing the importance of them taking care of the camera, how expensive the cameras were, so I think a lot of them were like: OK, I*

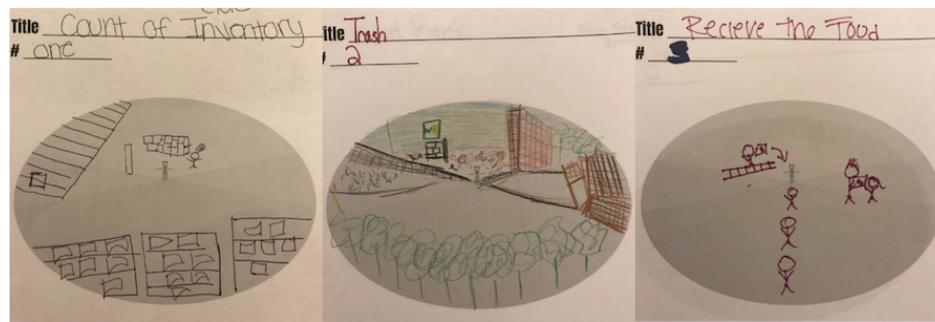
*don’t wanna be responsible if something happens.”*  
(T2)

The various experiences we saw in Mumbai and Atlanta around camera use highlighted considerations for introducing VR devices, especially for underserved educational settings. For some teachers, cameras were devices for tinkering; for others, these were fragile and expensive artifacts that needed care. For students, they were a source of curiosity but also of complexity and risk. This reveals some lessons for similar interventions, such as the need for finding balance in the introduction of these devices: between tinkering and instructions on using these devices, between tinkering and how teachers led with the fragility/cost of these devices (this is especially also true for underserved groups of users), and between the devices available and the number of students.

*The Storyboarding.* To better understand how students would engage with their storytelling assignment, we asked teachers to describe their prior experiences with storytelling for teaching. T10 told us that he shared biographies of well-known personalities: *“I loved stories of eminent mathematicians, so I choose tidbits from their life experiences and verbally discuss the morals and lessons in class.”*

There are other methods for storytelling that can be used besides storyboarding (such as narratives [32]) but this is not ideal for designing VR environments where new content creators need to invest time in laying out actors, objects, and other items in the scene before filming. No method is as good as storyboarding for this purpose, so we went ahead with this. While students at both sites had had discussions around stories presented in class, we found that they had not engaged in any formal storyboarding of scenes before, and we surmised that this contributed towards less engagement in the storyboarding phase. As was explained by T8: *“None of the students have done any kind of storyboarding before, so how can you expect them to realize the value of storyboarding upfront?”* This impacted student engagement and enjoyment in this phase of the study (we discuss this in upcoming sections). A student from Mumbai commented on how the exercise seemed pointless: *“I do not understand why we have to draw out each scene and write out a description. I mean, can we just please go ahead and use the cameras already? They seem so cool and I really do not care for doing more writing and drawing on a piece of paper—I want to go outside and shoot a movie!”* (S64)

Many students came up with creative, involved storyboards for scenes. While some teams appeared to enjoy the process more than others, we observed a general clarity about the goals of the storyboarding task. Figures 2-3 show some storyboards created by students from Atlanta and Mumbai. In Mumbai, students used a mix of Hindi and English, while in Atlanta, the storyboards were only in English.



**Figure 2: Examples of three storyboards created by a team in Atlanta. The first scene shows a food bank volunteer performing an inventory count and managing the bank; the second scene is an outdoor shot of a first-person perspective of a homeless person’s job at a trash dump; the third scene is another first-person perspective of a homeless person waiting in line at the food bank for his/her turn at the food counter.**

### Co-Creation and Co-Consumption of Content

We now present findings from the content co-creation and co-consumption the students engaged in (under the supervision of other participants) at both sites. We report how participants went about in teams co-learning best practices around filming a VR movie, designing workarounds to viewing these movies in groups, and reflecting on their experience of content creation.

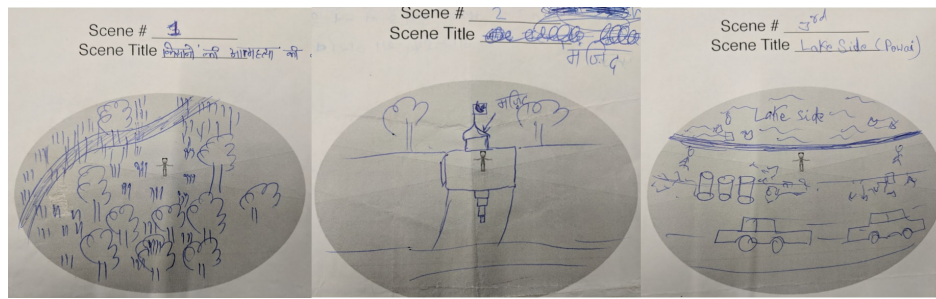
*Content Co-Creation.* The process of videography afforded students the room to fail multiple times and recover from failure. This iterative process of meaning-making was supported through the VR videography experience. A student from Mumbai described her team’s process of co-learning to use and work with the cameras: “It was trial-and-error. We would take multiple angle shots and then view them all on the mobile app immediately to see what they looked like. If we didn’t like something or wanted to change something, we’d retake the shot.” (S70) This learning ‘on-the-go’ protocol was prevalent among most groups; however, limited battery life (~2 hours) and limited memory (~5 GB) of the cameras restricted the students from exploring more creative shots or improving the quality of some shots. This issue was exacerbated by camera-sharing between teams, particularly in Atlanta, where there were more student teams. S45 in Atlanta said: “I love the final movie we made, but I wish I could change or redo a couple of scenes! We had limited time at the field and limited battery, so we could not make a couple of scenes perfectly as we’d have liked to.”

Storytelling with VR also offered an opportunity for physical engagement or embodiment. For instance, hiding the camera operator is a unique challenge that comes up with recording 360-degree content. Students encountered this on-the-go and had to identify workarounds in very little time. They did not undertake (nor did we encourage) the use of any

sophisticated movie editing software to edit out the camera operator; rather, students resorted to hiding strategies during the videography phase. A popular strategy undertaken in Atlanta and Mumbai both was to hide the camera operator behind still objects in the scene (e.g., trash can, tree, car) while the camera operator remotely controlled the camera using a mobile application. In some cases, students would attach the camera to objects or surfaces—such as taping the camera onto a tree or sticking it into the soil with the help of a wide stick. One team was shooting a few scenes in public locations—a bus stop, a temple courtyard, and a nearby lake. In these cases, the camera operator played the role of a bystander or pedestrian on her phone, thus becoming both an actor in the scene and the camera operator. We were interested to find that VR offered multiple and diverse opportunities for embodiment as well as an iterative process of failing and recovering from failure.

Students also used role-playing strategies and props in their movies. Examples from both sites are listed below:

- (1) In a scene that demonstrated deforestation in Mumbai, two students dressed up as traditional rural farmers, created an axe out of cardboard and wood, and acted out a scene where one of them was about to cut down a tree, but was stopped just in time by the other farmer.
- (2) A student at Mumbai played the role of a pedestrian who tosses a paper bag out onto a crowded street, while another student pedestrian picked up the bag and carefully placed it into the appropriate recycling can.
- (3) A team in Atlanta acted out a day in the life of a homeless person who gets food from a local food bank; he is dressed shabbily and waits in line for an hour until his turn.
- (4) Another team at Atlanta took the perspective of a college student who did not have money to secure food for



**Figure 3: Examples of three storyboards created by a team in Mumbai. The first scene shows a farm from the perspective of the farmer tilling the land; the scene title in Hindi says ‘Why do farmers commit suicide?’, highlighting the issue of suicides that many rural farmers committed due to crop failure and harsh working conditions; the second scene is at the entrance to a mosque in Mumbai (the scene title says ‘masjid’ or mosque); the third scene shows a lake in Mumbai, with garbage thrown inside and on the road despite the presence of trash cans (also shown in the picture).**

himself and role-played a day in his life. They strapped on the 360-degree camera on to one teammate’s head, and provided a first-person camera view of the entire day.

- (5) A team at Mumbai wanted to show how certain public places were kept clean, while others were kept dirty; they shot two first-person perspectives: one of walking inside a clean temple courtyard and another of walking outside on a messy street right next to the temple. In both shots, the students added voice-overs to discuss the lessons learned.

As examples above show, perspective-taking was a popular strategy across sites. Movies were created from perspectives of a homeless person, food-insecure student, food bank volunteer, bystanders at public locations, rural farmer, and many others. A student in Atlanta said: “When I created the movie from the perspective of the homeless person, we had to enact his day-to-day activities—such as waiting in line for food—and that’s when I realized how difficult it is to survive a day.” (S22) Empathizing with the situation was the goal in many of these perspective shots. A Mumbai student described her experience playing the role of a farmer: “Role-playing as a farmer was such an eye-opening experience. Just standing in the sun shooting the scenes on the field was so difficult! Imagine using a real plow to till the land all day in that heat!” (S61)

Storytelling with VR offered students an opportunity to make meaning of their physical surroundings as they figured out how these constrained them or forced them to move around and find objects they could leverage. Students at both sites had to grapple with the immutability of certain public locations. An identical adaptation of the storyboard during the videography session was difficult since certain public locations had a different layout, different objects in the scene,

and fewer/more bystanders than the students anticipated. But this situation also made students more accepting:

*“We were at a bus stop and wanted to shoot a scene there. But there were many people around and a lot of traffic, there wasn’t anything we could do about that—so we just had to work with it and position the camera so that we captured more of what we wanted and less of what we did not want. It’s hard to do this with VR—since you’re capturing a complete 360-degree image! But it’s also a more realistic representation of what the actual site is like, so that works in our favor!” (S68)*

**Content Co-Consumption.** Once the videography phase was completed, students edited their scenes (on iMovie/Windows Movie Maker) and uploaded their movies on YouTube/Roundme. YouTube movies supported 360-degree motion pictures with a narrator’s voice-over (recorded separately by students with a mobile phone microphone), while Roundme movies offered the additional capability of embedding text and audio interest points in specific locations of the 360-degree content. Regardless of the platform used, there were two primary modes of watching the movies: non-immersive and immersive. In the former, movies are seen on a screen analogous to non-VR content; the viewer can interact with the scene using his/her finger or cursor. In the latter, the movie is seen on a mobile device with a head-mounted display (HMD).

The first mode, which works well for group-viewing of content, was employed by teachers at both sites to show all the movies created by the teams to the other students at the end of the study. However, this mode lacks immersion, and teachers argued that it defeated the purpose of the medium; one teacher from Mumbai was concerned that the perspectives could not be fully experienced “as though you were in the shoes of the farmer or the homeless person” (T9) when



viewed on a flat screen. The second mode only supported 1-to-1 engagement, but offered a high degree of immersion. Students watched their movies in this mode, prototyping and testing out their shots throughout the videography process using cardboard viewers. S78 commented: *“It is silly to watch the VR movie on a flat screen, all the effort we put into making the movie is lost. You want an emotional and engaging experience—so you should watch it inside a headset only! How can you create a ‘feeling of being there’ on a flat surface?”*

By contrast, some teachers did not oppose the idea of group-viewing and said that this mode alleviated their concerns of using the headsets. T10 said: *“A flat surface is easier to watch the movie—less strain on the eye and it’s great for group viewing. Yes, we lose some immersion, but the general idea is conveyed this way as well.”* Another teacher argued that the non-immersive mode was not identical to traditional non-VR content viewing, in that VR movies offered a higher degree of fidelity: *“If you play a traditional movie in class, some kids will put their head down and lose interest. But if I show them a 360-degree movie on the same screen, they will be engaged because we can still interact with the scene and move around with the cursor, as the scene plays out.”* (T4) Here, we highlight that the option to select non-immersive VR content as the viewing choice was not intentional; rather, users negotiated and struggled with these two options for viewing and they derived different meanings for the two modes.

Overall, teachers preferred the non-immersive mode of content viewing in the classroom, more so because of limited hardware. In these discussions, we also briefly touched upon content sharing; teachers discussed the challenge of disseminating content to the students’ parents and other community members given the limited number of headsets:

*“Yes, YouTube is great to upload these movies and share them, but how will the students watch this at home if they do not have the headsets? When they go home and talk to their parents about VR, the kids are teaching their parents without realizing. This excites parents; the community talks about ‘Hey, this is the cool thing they are doing at school’. This morale about the school grows in the extended community. But how can we foster this if we do not have enough headsets to start with?”* (T9)

This challenge of sharing content in homes with the families was not expressed in Atlanta, possibly because the teachers in Mumbai were especially motivated to extend the students’ engagement with VR beyond the center. In Atlanta, on the other hand, where experiential learning was conceivably more commonly leveraged and the novelty of VR lower overall (e.g., some students had cardboard viewers at home), teachers appeared less concerned.

### Co-Learning Social Justice

We now focus on the outcomes of the content creation experience as well as the meaning students and teachers constructed through an interrelated co-learning process. Participants co-learned the VR experience in terms of enjoyment, engagement, and empathy, with regards to both the process and outcomes of the exercise of storytelling with VR.

*Engagement and Enjoyment.* At the culmination of our study, we gave the students a post-project survey, asking them to rate their engagement and enjoyment levels during four of the general activities—the introductory workshop, the brainstorming and storyboarding, the outdoor videography, and the post-production. They were asked to rate their level of enjoyment on a scale of 1 to 5 (where 1 meant *“I did not enjoy this activity”* and 5 meant *“I loved this activity”*). Mumbai participants demonstrated higher levels of engagement in general than Atlanta participants. This may be because VR (and technology in general) had greater novelty in Mumbai. S66 said that she *“had never even thought she would get to make any movie, leave aside a VR movie”*, speaking to the novelty and consequent excitement most students in Mumbai had for all the activities.

At both locations, engagement levels lowered during the brainstorming and storyboarding stages. This aligns with our earlier findings where some students complained that they did not recognize the value of writing out the different scenes and thought storyboarding was *“a waste of time”* (S15). Some students had also reflected the willingness to *“get out of class as fast as we can and start using the 360-degree cameras”* (S44) and this led to a spike in engagement levels during the videography phase. At the same time, however, in our final discussions, one student from Mumbai commented:

*“Once we actually went outside to shoot the movies, I think we all realized the value of the storyboarding exercise. While we initially planned to just take each scene at a time, the fact that we had these storyboards helped us so much! I didn’t have to think about what to act out in each scene... it was just like following instructions that we had already written out.”* (S63)

In our post-project survey, we included a question on how proud students felt about their final movies, asking them to rate this feeling on a 1-5 scale. We wanted to understand how satisfied students felt with their final movies. The average rating across both sites for this question was 4.23/5.0. (This number was 4.34 for the students in Mumbai and 4.12 for the students in Atlanta—a difference that might be attributed to cultural factors.) The numbers suggested to us that students were, in fact, proud of what they had produced. This was further substantiated by quotes such as the following

from S80 in Mumbai: *“Watching my final movie in its entirety was incredible—I felt so thrilled and happy. Who would have imagined that us ordinary students could make something as complex as a VR movie. I’ve never been given this level of responsibility before for something so complicated.”* (S80) Here, pride regarding the final movie was a consequence of conceptualizing their projects as a reflection of their responsibility as well as *“things of their own”*. Another student at Mumbai similarly commented: *“I really enjoyed creating the script and writing the story, especially since you let us write whatever we wanted to write. I felt like this was MY story. Whatever was in my mind—I could share with others through this new medium. I found that very powerful.”* (S65)

**Building Empathy Through Storytelling.** We explored the impact of storytelling on the notion of empathy through VR-mediated interactions with the students’ surroundings. Since the themes were different across sites, we first consider our findings from the sites individually and then discuss overlaps in data. We start with findings from Mumbai.

Prior to the Mumbai study, we had asked students to discuss their understanding of the theme ‘respect’. We found that most students thought of respect as something they expressed towards other individuals. Students responded with phrases such as *“I respect my parents”* (S66), *“We should respect our teachers and elders”* (S82), and *“I respect people with disabilities”* (S74); T9 pointed out that students viewed respect through a narrow lens and did not engage with respect towards concepts, groups of people, and places. Therefore, the teacher assigned student teams themes of respect towards farmers, other religions, public spaces, homeless children, and the environment: these themes did not fall under the traditional notions students had around fostering respect.

To see how students’ perceptions around respect had changed, we solicited feedback from teams at the end of our study. One student shared what he learned about farmers:

*“I realized how difficult it was to grow the grains and crops that we eat everyday, and I had no idea farmers worked so much. Just shooting VR movies in that heat was bad; imagine working there all day!”* (S64)

Another student told us that she had *“never consciously thought about the amount of work that went into keeping a single street clean, given the amount of trash people casually dump every day”* (S62). Teachers encouraged empathizing with the user group or place selected for the VR movie. T9 discussed how her desired learning goals were met with the activities:

*“Just being able to grasp the topic in any way—the kids never really realized the significance of these issues. I could care less about the facts they learn in science about preserving the environment and best farming practices, what they really got out*

*of this project is the ‘realization’ that respecting farmers or the environment is crucial. And this realization will take them a long way. You see, the emotion is the real difference to me—my students should be able to tell me that ‘I didn’t just go there, but I went there emotionally.’”* (T9)

Similar to the findings from Mumbai, at the beginning of our study in Atlanta, we asked students to write out words that immediately came to their mind when they thought of *“hunger and homelessness”* in their city. The top 20 words written by the students included *broke, smelly, depressed, dirty, dangerous, addicts, unwanted, frightening, and mean*. Teachers told us that a negative perception of the homeless persisted because students remained largely detached from the affected population, and no amount of reading in a book could *“generate that empathy towards the homeless unless they see it or experience it for themselves”* (T6).

At the end of the study, we asked students to answer how they perceived this theme once again. One student said, *“I learned that everyone’s situation isn’t the same so you just can’t judge people based on how they look or what perceptions you may have of them.”* (S35) Another student reflected on her initial response to this question, saying, *“I learned that most of the stereotypes aren’t true. Most homeless people could look just like you and me. People think it’s the homeless persons’ fault that they are homeless but that is so wrong!”* (S33) Some students reflected on the new information they had gathered through the process of documenting their experiences: *“I didn’t know that there were homeless college students, so many more than you would think. And also so many college students who are not able to afford three meals a day.”* (S26) The understanding that *“homelessness cannot be solved in a day, and this is actually a very long and hard process”* (S53) was widely recognized in the comments we received, and some students acknowledged that this was a new lesson.

Our findings conveyed that students at both sites had engaged deeply with the themes. They now had a more nuanced understanding of the themes they had worked on, during and after the storytelling exercise. Teachers at both sites reported that they were very satisfied with how their students had engaged with their environments, using VR as their medium. An understanding of this meaning-making process is what we were after, as we intended for students to immerse in their environments using VR.

## 5 DISCUSSION

We now share lessons from our multi-sited research that might inform richer understandings of the possibilities for VR’s future as an everyday technology, in new contexts and domains, using novel methodologies, across new geographies. Our larger vision is for VR to find integration in everyday contexts in ways that are meaningful to diverse users.

### Integration in New Contexts and Domains

Although our work focuses on learning environments with well-defined roles for learners and educators, we contend that the everyday context we explore shares many similarities with other *in-the-wild* informal learning environments where learners and educators relate in several other different ways. These environments could include hospital settings with doctors, health workers, and patients. They could also include homes and workplaces of various kinds, where VR might allow individuals to engage with and gain expertise in diverse domains. Larger and more constrained settings, such as formal schools and community centers, among others, could explore the value of VR’s affordances as well. In particular, we believe our findings can illuminate three aspects to consider when trying to fruitfully tap into low-cost VR’s potential towards teaching and learning—(1) the need for a method for supporting stakeholders in agreeing on ways of using the technology that are meaningful to all of them, (2) the possibility for VR to support engagements with one’s surroundings through meaning-making rather than consumption of content alone, and (3) defining the social and technical infrastructural requirements for deploying VR. Next, we discuss each one of these aspects in detail.

Just as our teacher and student participants assigned different meanings to VR—a valuable skill to be learned, a novel artifact with charisma, or simply a means to support other learning, it is conceivable that with different demographics and/or environments, a new set of meanings for VR might emerge. In Atlanta, for example, it was more routine for teachers to engage with new technologies in their classrooms, which led them to view VR as “another new technology” that a project might involve. For them, VR had specific affordances that could be contrasted with other technologies. In Mumbai, teachers tended to see VR more as a medium of communication, to give their students wider exposure to the world (that they were also keen to share with families, more than in Atlanta). Such interpretative flexibility suggests the need for practitioners to explore methods that can support stakeholders in reaching closure. As Noss and Hoyles concluded in their analysis of Logo’s integration in schools, disregarding diverse interpretations among stakeholders can hinder meaningful technology adoption [57].

Prior work has shown several different and compelling affordances of VR, but leveraging VR as a unique medium of communication as well as a way to engage with one’s surroundings towards meaning-making (as we saw in our research) could serve as a stepping stone to its integration into more complex environments. Using VR for content creation gave students the opportunity to become familiar with the mechanics of the technology, as well as ways of using VR *external* to the immediate viewing experience—that is, thinking

purposefully about perspective-taking [53], and capturing and communicating information through VR. We note that using VR in this way leveraged how both learning environments we studied did not have stringent rules regarding what to learn and how, other than a general focus on content creation. This gave students the freedom to explore contexts outside of their classrooms, making content creation feasible, if not completely unrestricted. It is possible to imagine that diverse learners might find it even easier to create content without having limitations on the places they can go, as one of the Atlanta teachers mentioned. As a result of this freedom, learners might be able to create more content to work with and be more likely to encounter ideas they care about and want to convey, further engaging perspective-taking and role-playing. Integrating VR through such activities would also be aligned with prior recommendations for research to explore how VR can be a new communication tool [13], or how mixed reality might be leveraged for students to engage with their realities [37].

Finally, addressing questions of perceived affordances can bring attention to infrastructures necessary to integrate VR—both technical (cameras, electricity, access to mobile phones) and social (teaching capacity). In our case, teachers’ stress over the meaning of VR as a tool for the classroom and less of an expressed concern over infrastructural limitations—despite the underresourced settings—led us to design our study by making minimal assumptions about infrastructural requirements. Our ability to conduct both interventions to the end without major infrastructural problems suggests that low-cost VR can feasibly be used in underserved, less-resourced informal learning environments, in addition to better served and better resourced ones.

### Methods for Integration

The introduction/integration of a new technology, with its attributes and affordances, poses a challenge for stakeholders: they need to engage in a negotiation of the meaning they will assign to it, considering their current and possible future needs. Given how new VR still is to the average user (despite extensive research advancements over the last two decades [1, 52, 73]), it is essential for us to consider how to support the meaning-making process of stakeholders unfamiliar to this technology. We argue that such learning can greatly inform the future of VR, if and when it is unleashed more widely in the public sphere. We now reflect on the methods (including workshops and design processes), through which we scaffolded the learning of how to use VR in our sites, supporting users in their meaning-making journey. We discuss possible methods for addressing three conflicting conceptualizations preventing teachers and students from reaching goals that were meaningful to them: (1) cameras as objects for tinkering vs. objects of instruction, (2) cameras as objects

for tinkering vs. fragile/costly artifacts, and (3) storyboards as boring/hard media vs. useful tools for storytelling.

While students were eager to use cameras as objects for tinkering, they also complained about the learning curve for using cameras and storyboarding in VR. Teachers also wished for a longer training period for camera use before the student went out and shot videos. Recommending and sharing best practices for hiding the camera operators, positioning and orienting cameras and objects in a scene, and supporting VR storyboarding can be facilitated by creating training protocols and guides that give room for experts to talk to new VR users. Many students developed these techniques through “*trial and error, and by making many mistakes and taking multiple shots*”, and we acknowledge this as a feature of the meaning-making experience. Co-design methods for learning need to, therefore, consider these factors so as to offer a balance between tinkering and instruction.

To address the issues of teachers’ perception of the cameras as expensive and fragile—and how this perception hindered students’ willingness to tinker with them—we could add activities with the cameras during the co-design sessions that can highlight the resistance of these devices. However, our observations revealed that the goal of students when working with VR was to be able to tell a story that was engaging and relatable, regardless of whether the story made use of high-quality videography and sophisticated editing or not. This is an important finding because it conveys that the quality of tools used or lack of expert editing skills may not necessarily be bottlenecks for the VR content generation experience to be engaging and potentially instructional. We also recommend examining the ‘timing’ of delivery of these training/co-design sessions so as to enable the creation of a safe space for learning and growth, facilitating students’ iterative exploration with technology.

Students found it difficult to identify with the value of storyboarding. However, once they went out to film the movies, they realized the relevance of storyboarding and often re-engaged with it to iterate on their creations. Rethinking traditional flows of content development (“storyboarding precedes filming”) for students who may be captured in the charisma of filming with a new technology such as VR may help with reinforcing the objectives of comparatively mundane activities like storyboarding before filming. For decreasing students’ initial aversion to storyboarding, a following iteration of our work could propose that students brainstorm and represent their stories with other mediums (such as narratives) and ask that they themselves contrast the pros and cons of both mediums. The storyboarding exercise could also be organized at a later stage of the creation process, as all aspects of student creativity and exploration were positive outcomes of the meaning-making experience.

Overall, at both sites, we saw students looking for more opportunities to conduct trial and error with VR. For example, they strove to get more time to record material for their stories for the purpose of examining it later and deciding what needed to be recorded again. This suggests the need for VR interventions to explore contextual ways, via co-design or alternative methods, to support the time and space for students’ iterative work. In addition, to support iterative meta-cognition of the underlying ‘theme’, we can, through new methods, consider making space for ongoing reflection of their content creation activities.

### Exploring New Geographies

It is important to address how we align VR experiences with the goals of a new geographical location—one that has a new culture, new stakeholders, new value systems—in ways that require minimal intrusion or deviation of user behavior, but also make a deep impact on furthering desired outcomes. Certainly, new learning challenges may arise as VR gets introduced into new, diverse domains with different motivations. If instead of storytelling on hunger and homelessness in Atlanta, the objective becomes to learn about a specific surgery in a public hospital in Ecuador, or to examine the insides of the earth in a private research center in Singapore, the challenges of engaging may be very different. Thus, we suggest that future work might look into the use of VR in a range of environments, whether it involves learning new agriculture practices, becoming sensitized to issues relating to gender-based violence, or engaging in various health-seeking behaviors. It might also examine the identities and backgrounds of those who are creating the content. Both the creators as well as the perceived affordances of the technology for the specific environment will shape the meaning made of and with VR.

The idea of VR as a new technology for users in the Global South *and* Global North presents us with a unique opportunity to examine learning and sharing of VR experiences across borders, since everyone is potentially a novice. (We tend to agree that the “Global South” includes underserved parts of the North, but there is some tension here since infrastructural constraints, cultural norms/limitations, etc. vary.) Unlike prior learning technologies—where technology transfer typically took place in one direction (*i.e.* from the North to the South)—with VR, we might aspire to support knowledge transfer in both directions, where domain experts in the South and North can become champions of VR integration in their respective contexts for *other* contexts across borders. To facilitate this, we must take coordinated steps with stakeholders, VR practitioners, and researchers in new geographies to understand how to situate this new technology within the culture of a new site, a new use case, and a new user. We must also align methods of learning to use or

consume VR with the operational hierarchy of these new sites, by addressing questions such as: *Does the site have a manager or authority who decides the scope of VR use? Who gains from the use of this technology and what are these gains?* For example, one role VR can be desirable for is that of a mediator of empathy-building for learners. In both Atlanta and Mumbai, students reported VR as an important actor in renegotiating their perspective on empathy as well as on social issues around them. Our work thus suggests VR as a type of charismatic technology, as Ames describes it [3]. We highly encourage more field explorations of this medium in realms outside of storytelling such as for math learning, or to examine scientific rather than social realities, since the charisma of VR might take a different shape in those scenarios, among others.

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