Computer Assisted Language Instruction Consortium

CALICO JOURNAL (ONLINE) ISSN 2056–9017

Article

Building a City in the Sky: Multiliteracies in Immersive Virtual Reality

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Abstract

The conceptualization of multiliteracies initiated by the New London Group (NLG, 1996) emphasized the situated nature of language use as a socially complex network of multimodal engagement. Inspired by this view of language and literacy, computer-assisted language learning and second language acquisition scholars have advocated for a broader scope of second language learning to include the development of multiliteracies (Reinhardt & Thorne, 2019; Warner & Dupuy, 2018). In this conceptual article, we explore the potential affordances of immersive virtual reality (IVR) for the development of multiliteracies. As we attempt to construct a working theory of IVR as a catalyst for understanding and creating multiple forms of language in use, we draw on existing literature as well as on data from our multi-year study of multilingual adolescents engaging in multimodal activities using the Meta Quest headset. The interactions between adolescents and researchers were designed to maximize key IVR affordances (embodied cognition, presence, agency, and contextualization), and examples from the IVR sessions suggest how the adolescents are developing multiliteracies. We conclude with ideas for future research that focus on empowering L2

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Received: 14 April 2022 Accepted after revision: 12 November 2022

CALICO JOURNAL VOL 40.1 2023 24–44 https://doi.org/10.1558/cj.22838

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learners to express themselves as they develop the necessary knowledge and skills to engage in multimodal literacies.

Keywords: affordances of IVR; embodiment; immersive virtual reality (IVR); multiliteracies; social VR.

1. Introduction

The New London Group (NLG, 1996) represents a gathering of literacy scholars who first convened in 1994 to reimagine literacy teaching and practice; this new vision acknowledged various communicative technologies within an increasingly multilingual society. This group's conceptualization of *multiliteracies* focused a spotlight on two "multi" dimensions of "literacies": the *multilingual* and the *multimodal*. The increasingly multimodal nature (print, graphical, audio, etc.) of textual media has situated language use even further as a socially complex network of multimodal engagement, hence moving the notion of language beyond words and utterances. Over the past few decades, communicative acts of reading, writing, speaking, and listening have evolved to represent multiple, multimodal representations of meaning across disciplinary contexts, cultures, and discourses, even within a given language (Hovious et al., 2021; Yuan et al., 2019). In addition, the lack of neutrality of textual media (Street, 2003) necessitates critical exploration of sociocultural contexts and histories that shape which information gets privileged or excluded across modes of communication (Arya, 2022; Kern, 2021; Warner & Dupuy, 2018).

The NLG's vision of multiliteracies inspired many in the field of foreign language (FL) and second language (SL/L2) studies to re-examine and re-envision how literacy and subsequently multiliteracies are essential for L2 learners. Initially, for teaching L2 reading and writing, a more integrative approach to literacy was proposed, one that examined "reading and writing in their contexts of use" and "what people mean by *texts,* and what texts mean to *people* who belong to different discourse communities" (Kern, 2000, p. 2). Similarly, emphasis was placed on L2 learners' development of literacy skills as an integrated set of linguistic, cognitive, and sociocultural skills, rather than focusing solely on language skills (Swaffar & Arens, 2005). Furthermore, reading and writing practices were acknowledged to be influenced in part by the social environment, but also in part by the emerging technological mediums that multilingual learners use to engage in these practices (Kern, 2015).

In broadening the scope of language learning and teaching to include the increasingly multimodal nature of language and multiliteracies, FL/L2 educators have advocated for the integration of digital literacies, which broadly

involves engagement in multiple, overlapping modes of communication within online spaces (Reinhardt & Thorne, 2019). Second language learners can reappropriate online content for new spaces, including digital games. Digital literacies enable meaning-making in L1 or L2 that is multimodal, hence integrating written and spoken language with images, gestures, and haptics (i.e., embodied sensory engagement). Multiliteracies scholars Hull and Nelson (2005) analyzed a child's original digital music video, in order to illustrate the semiotic power of integrating such modalities for generating meaning that is greater than the sum of its constituents. We situate our work within this understanding of digital multimodality as we explore the potential of immersive virtual reality (IVR)[1] for fostering language and literacy development for L1 and L2 learners.

The engagement with and production of dynamic multimodal texts (i.e., texts with embedded animated qualities) and all of the aforementioned examples of multiliteracies are embedded in IVR as part and parcel of the technology. Transformation of the contextual surround begins at the very moment of activating the headset and controllers used to transport users to various destinations that can be seen, heard, and even felt; this phenomenon is known in the literature as the affordance of *presence* (Bailenson, 2018; Dede et al., 2017; Johnson-Glenberg, 2018; Mennecke et al., 2011; Radianti et al., 2020; Sherman & Craig, 2003; Slater & Sanchez-Vives, 2014). The notion of presence has been defined as "the fundamental characteristic of VR" (Bailenson, 2018, p. 21), as well as the feeling of "being there" (Slater & Wilbur, 1997, p. 606). Other distinguishing affordances include *embodiment*—the haptic, immersive feeling one has in IVR—and the *agency* one has when navigating and creating within the virtual world (Johnson-Glenberg, 2018). Three-dimensional, 360-degree virtual environments have been noted to enhance *contextualization* of learning (Dalgarno & Lee, 2010), and of language and literacy learning in particular (Lan, 2021). Such enhanced contextualization allows for full (embodied) engagement with dynamic multimodal texts, which may afford deeper insights into key conceptual content and communicative practices.

In this article, we offer a descriptive account of how learners' multiliteracies can be developed in IVR environments that involve a full-bodied experience in meaning-making. We highlight examples from relevant literature that have collectively informed our working theory about the potential affordances of IVR for fostering knowledge, skills, and abilities in multiliteracies for language and literacy learning. In the spirit of culturally inclusive research practices, we center our account of such affordances from the perspective of pre-adolescent and adolescent readers, who were positioned as *co-learners* and *co-researchers* in our project. As such, we share examples of how participating youth engaged with researchers in multimodal meaning-making while immersed in VR using Meta Quest headsets and MultiBrush, focusing on an activity involving a

project we call "Building a City in the Sky," which involved engagement in multiliteracies (i.e., reading, writing, drawing, verbal interactions, mapping). Following the illustrative account of our working theory of IVR multiliteracies, we conclude with suggested avenues for future research on how IVR can promote language and literacy development.

2. Affordances of IVR for the Development of Multiliteracies

Immersive VR is distinguished by its enhanced immersion in interactive, virtual 3D environments, which is mediated by (a) their associated affordances; (b) how learners interact with the technology; and (c) how educators and software developers design engaging virtual learning environments. Immersive VR has the power to transport a user to imagined events or places completely disconnected from their actual physical surroundings (Dede et al., 2017). While video gaming and cinema also have means of engaging users in such digital content, IVR has been described as "the illusion of non-mediated connectedness" (Selverian & Lombard, 2010, p. 35), which can seem realistic enough to result in panic or fear during a simulated earthquake or falling from great heights (Bailenson, 2018). This state of immersion is mediated by key technological features (i.e., head-mounted displays, hand-held controllers, real-time 6-degrees-of-freedom spatial tracking, etc.), which in turn enable the affordances of presence (Slater & Wilbur, 1997). Through these affordances, users interact with a variety of digital content such as simulated 3D worlds or immersive videos of real-world scenarios in a variety of embodied actions such as walking, standing, reaching, pointing, holding objects, and triggering dynamic or scripted actions. This interactivity yields a profound sense of agency, while the fidelity of representations yields immersive contextualization.[2] In addition, social interaction among users in a virtual environment, especially goal-directed substantive and coordinated activity, works together with immersive affordances to yield a sense of co-presence and a feeling of "being there *together*" among users (Mennecke et al., 2011).

The growing body of research on IVR remains heavily focused on usability, with only a small percentage focused on learning theories or measured outcomes. Across several meta-analyses of empirical studies of learning performance, findings are mixed. One meta-analysis of 35 studies concluded that IVR using head-mounted displays (HMDs) in a variety of domains (medical education, science education, physical education) may be more effective than non-immersive learning approaches in terms of spatial thinking, creativity, and analogical reasoning, albeit with small effect size, and that HMDs have a greater impact on K–12 than on higher education (HE) learners (Wu et al.,

2020). On the other hand, another review of 36 studies revealed the surprising finding that highly immersive IVR with HMDs may result in inferior learning outcomes (measured by content tests, assignments, and projects), when compared with non-HMD interventions, both in K–12 and HE (Luo et al., 2021). A synthesis of 18 studies in K–12 and HE suggested that the main advantage of IVR is the affordance of first-hand experiences that would not be accessible in the real world, thus offering opportunities for experiential and situated learning for understanding alternative perspectives on critical social issues (Di Natale et al., 2020). Scholars agree that understanding the potential of IVR for educational purposes is in the nascent stages, and that more research about particular learning affordances is needed (Di Natale et al., 2020; Luo et al., 2021; Radianti et al., 2020).

A few educational researchers have theorized about how IVR can promote learning (Dalgarno & Lee, 2010; Dede et al., 2017; Makransky & Petersen, 2021). These models typically reflect cognitive and/or social aspects of learning; one such model emphasizes a constructivist point of view, asserting the notion of richer cognitive engagement via embodied exploration and the construction and manipulation of virtual objects and structures (Dalgarno & Lee, 2010). However, it remains unclear whether such embodied exploration leads to more learning (Makransky et al., 2019). For the purpose of literacy development, salient affordances of multimodal interactivity in 3D virtual environments include (a) *experiential learning* that would otherwise be impractical or impossible to access; (b) learning tasks that foster the transfer of knowledge and skills to real situations through the *contextualization of learning*; and (c) *collaborative learning* that is less possible in actual environments which typically have more spatial constraints (Dalgarno & Lee, 2010). A social constructivist framing of VR affordances positions learners as co-creators of meaning through participation and interaction (Dede et al., 2017; Huang et al., 2010). Mills and colleagues (2020) explored a project during a beginning French course that used VR to immerse students in Paris using visual, auditory, and sensory modalities; learners were able to envision, experience, and understand the diversity and complexity of Parisian culture (Mills et al., 2020). They recorded themselves with 360-degree cameras, immersed in credible and engaging cultural situations, and imagined their future role in that target cultural community. Hence, the dialogic construction of reality in IVR can expand what is typically possible in the learning process. Learners can negotiate positionality and meaning-making in new, more embodied ways when exploring literacy in such an immersive context.

A synthesis of existing educational research on IVR, primarily in HE, seems to acknowledge both cognitive and affective factors in learning that have led to the theoretical framework called the Cognitive Affective Model of Immersive

Learning (CAMIL) (Makransky & Petersen, 2021). The CAMIL framework classifies *presence* and *agency* as psychological affordances of learning in IVR, and suggests that these affordances influence six affective and cognitive factors, which in turn play a role in knowledge acquisition and transfer (see Figure 1 for a modified version of the CAMIL). Key to this theoretical model is the notion that media (content) interacts with method (use), and that certain pedagogical or instructional approaches are particularly relevant in IVR. The idea that the media in IVR must be accompanied by effective pedagogy is echoed by others (Huang et al., 2010). This suggests that IVR learning tools should be developed with an explicit focus on the affordances of IVR, which we return to in greater detail in section 3.2, "VR Tools and Interactive Tasks for the Development of Multiliteracies."

For language and literacy development within K–12 learning contexts, theoretical frameworks of IVR affordances are lagging. Immersive VR technology is viewed as an extravagant purchase for state-funded schools that struggle to ensure internet access (Araiza-Alba et al., 2022). In their systematic review of studies about the potential impacts of IVR on learning, Tilhou and colleagues (2020) found seven studies that highlighted the importance of IVR for enhancing phenomenological understanding of various scientific concepts such as the ecological impacts of natural disasters, yet concluded that there is a need for theoretical clarity on particular affordances for enhancing key academic skills such as reading. A review of the growing body of research on IVR for language learning in HE found that two key affordances of IVR are the simulative support of the target language environment and the bodily interactions during language in use (Chun et al., 2022). Other studies have shown that L2 vocabulary learning is aided by IVR, namely, the kinesthetic affordances of an IVR system called Words in Motion that may foster embodied cognition (Aikawa, 2021; Vázquez et al., 2018) and enhanced learner engagement (Tai et al., 2020). In addition, an IVR game called Crystallize designed for learning embodied aspects of culture, namely, *bowing* in Japanese culture, was shown to be effective for enhancing learner presence and the particularities of bowing in social contexts (Cheng et al., 2017). Finally, when using an IVR language learning app for role-playing (i.e., purchasing a toy and interacting with a virtual avatar), learners experienced a high degree of agency and demonstrated learning gains (Ou Yang et al., 2020). Immersive VR is also being used as a tool for researching L2 pragmatics. When learners put on a headset and produced targeted speech acts, they attended to various audio-visual cues in the VR space and used them to guide their actions, while also feeling that VR evoked greater emotional reactions as compared to doing the same task after watching a video on the computer (Taguchi, 2021).

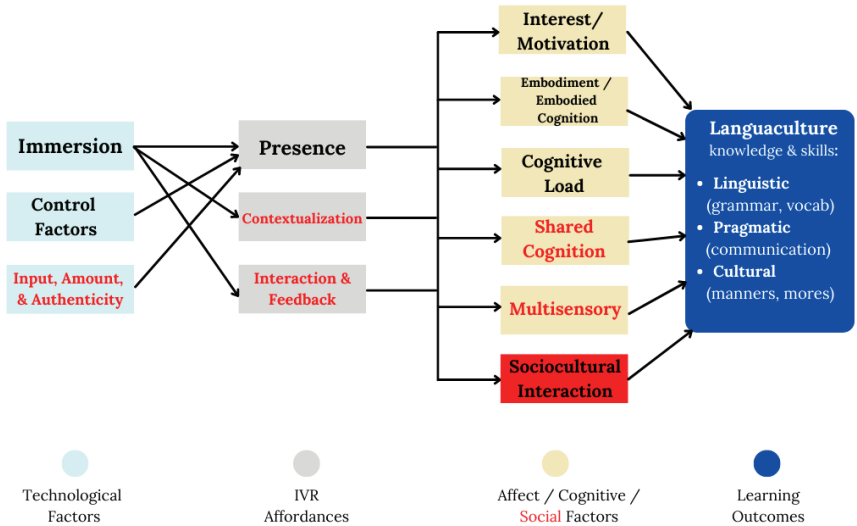

Figure 1: Proposed model for mediating factors in L2/languaculture learning (Chun et al., 2022).

The empirical and theoretical works summarized above informed our initial model of IVR for the development of L2/languaculture learning (see Figure 1). The IVR affordances of *presence*, immersive 3D 360-degree *contextualization*, and *interaction and feedback* that IVR offers are conjectured to be key (Chun et al., 2022; Huang et al., 2021; Lan, 2021).

A key principle proposed by Makransky and Petersen (2021) that serves as a theoretical anchor for our work is that it is not the medium of IVR itself that causes learning, "but rather that the instructional method used in an IVR lesson will be specifically effective if it facilitates the unique affordances of the medium" (p. 940). Hence, it is important to clarify the particular affordances provided by the tools and tasks we selected for engaging our young co-researchers in IVR. The following description is a narrative of the development of our project and the contextual factors that led to decisions about tools and activities used with our young participants.

3. Literacy Project Using IVR

We recruited five youth participants ranging in age from 8 to 14 through our university-housed reading clinic, which serves the surrounding community by providing reading and writing enrichment support for those identified as having difficulty in one or more areas of literacy (reading comprehension, spelling, etc.). Parents of youth who live within a predominantly Latinx/

Chicanx community and speak at least some Spanish at home requested services that would help to improve academic performance which requires grade-level reading, writing, and communicative abilities. Both parents and their children expressed interest in trying out IVR as a substitute for more traditional approaches that typically include paper-presented letter–sound matching exercises, skywriting, and repetitive exposure to particular spelling patterns through decodable texts. Such approaches may be effective for fostering the development of sound–print connections, but the full sensory approach afforded by IVR may be more effective for fostering the automaticity of skills. Further, reading engagement in modern society involves more than decoding (i.e., sounding out words) and determining key ideas. It is equally important to include texts that are designed to foster metacognitive thinking skills, particularly for engaging in critical analysis of textual ideas (Arya et al., 2022). Recent literacy research has highlighted the importance of fostering critical reading at the very earliest stages of literacy development (McClung, 2018). To put it simply, texts that reflect actual textual media for authentic reading purposes (e.g., learning about new ideas, connecting with important disciplinary themes, etc.) are an important part of the "reading diet" for students in the primary grades. The immersivity and flexibility of IVR technologies allow for focusing on multiple aspects of literacy development: word building, storytelling, creating characters, plotting, and outlining, all in a 3D space that is adaptable to the particular needs of students.

Our project began in the spring of 2019, starting with weekly sessions in parallel with the school year, conducted on a one-on-one basis (participant + student researcher) for approximately an hour. All of the sessions were video-recorded; we have accumulated video data that span three years, resulting in 82 recorded sessions that last an average of 60 minutes (see Table 1). Immersive VR sessions often involved all participating co-researchers, which included the youth, the undergraduates, and the graduate students. All members wore either wired HTC VIVE headsets (during earlier sessions) or Meta Quest headsets while interacting with one another. The goal of each session was to gain a better understanding of how IVR can be utilized to facilitate learning and practice in multiliteracies in ways that real-life mediums cannot easily replicate. As briefly mentioned earlier, this conceptual piece serves as an initial theorizing stage of our long-term empirical investigation. Our theorizing account is a direct response to methodological scholars who have criticized the commonly observed practice of large-scale investigations in the absence of initial theorizing via qualitative introspection of salient data artifacts (Maul, 2017; Sablan, 2019).

Table 1: Timeline of Data Collection Across Various Participants and IVR Apps

Pseudonyms[3]	2019	2020	2021	2022
Shaun	Drawing a multimodal narrative in Tilt Brush.			
Zelda	Drawing and remixing environments in Tilt Brush; adding text and dialogue in custom environments.	Drawing in Tilt Brush; cross-platform play with VR/Desktop in Roblox.		
Christian		Drawing multimodal narratives in Tilt Brush.	Drawing in MultiBrush; co-op play in Rec Room.	Designing environments and playing word games in MultiBrush
Linus Kennedy			Exploration in Wander; designing environments and playing word games in MultiBrush; co-op play in Rec Room.	Designing environments and playing word games in MultiBrush; co-op play in Rec Room.
Nicholas Cooper				Bilingual word games in MultiBrush.

3.1 First Theorizing Attempts

As depicted in Figure 1, our proposed theoretical model built on Makransky and Petersen's (2021) CAMIL and added factors particularly important for language and literacy learning, such as the sociocultural context (see also Chun et al., 2022). In addition, one of the key debates in educational research is whether it is the media or the methods of instruction that promote learning (Kozma, 1994). Some scholars have posited that the medium is the primary influence in socio-cognitive development (McLuhan, 1964), while others maintain that the ways in which media is presented and used (i.e., methodology) are what is most pertinent for learning (Clark, 1994). With particular regard to IVR, we agree that media must be used in tandem with methods, and that "certain methods which facilitate the affordances of IVR are specifically relevant in this medium" (Makransky & Petersen, 2021, p. 937).

3.2 VR Tools and Interactive Tasks for the Development of Multiliteracies

For our project, we designed purposeful IVR-enabled tasks that involved the use of 3D drawing applications such as Tilt Brush and its multiplayer descendant MultiBrush, which provide users with a host of tools for collaborative embodied construction of 3D models and handwritten text (stories). The high-level interactivity has been noted to allow users to create meaningful representations and manipulate their features with hand controls and body movements (Haeyen et al., 2021), hence engendering a sense of *inhabiting* a multimodal text. The open-ended nature of these platforms lends itself to different frames for creative activities such as storytelling or artifact design. In addition, anchoring activities within a sociocultural context allowed our co-learners to engage in collaborative constructions (multimodal stories) that reflect locally relevant phenomena, hence building stronger sociolinguistic connections with real-world practices.

Since the principal purpose of this study is to begin theorizing about IVR for language and literacy development, and not to present a systematic analysis of our extensive session data, we selected specific examples of sessions with our adolescent bilingual learners, primarily from the "City in the Sky" activity for its rich context involving playful co-construction of an immersive world in which we observed a variety of multimodal literacy practices and modes of thinking/acting (e.g., artistic, scientific). We specifically focused on relevant apps that emphasized place-based explorations (e.g., Wander, Geoguessr), because, like "City in the Sky," they are environmental arenas for rich contextualization, but also act as portals to existing cultural worlds for literate practices, rather than as a blank canvas for one to be invented. These

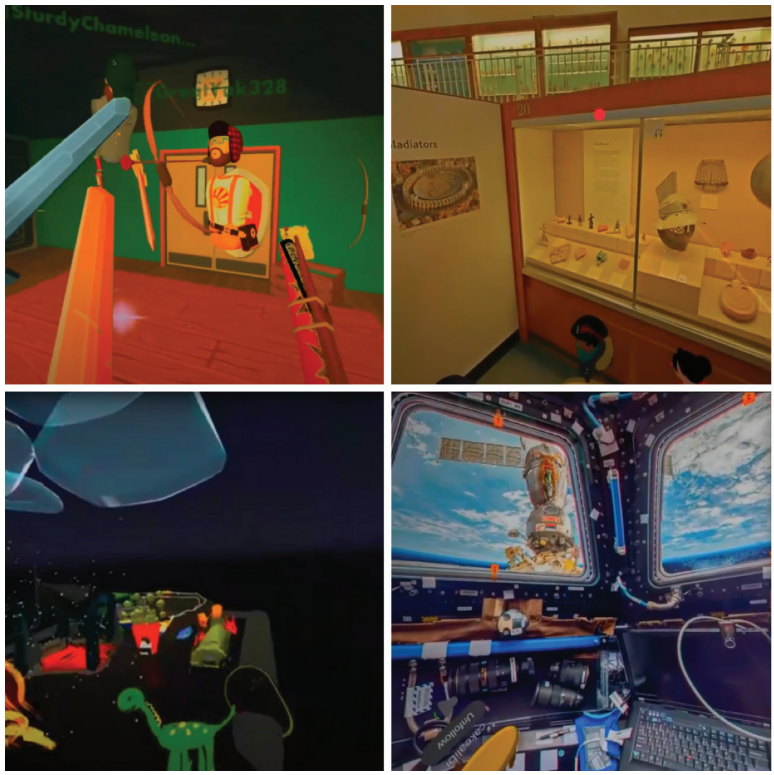

Figure 2: Screenshots of various IVR applications from a first-person perspective taken from our session data.[4]

examples illustrate particular affordances of embodied cognition, presence, agency, contextualization, and collaboration through IVR.

MultiBrush was used with one of our participants, Linus Kennedy (LK), who is a 13-year-old multilingual learner with a white European background and who identifies as a male using the pronouns he/him. LK participated in a small project, which we refer to as the "City in the Sky" and which spanned several sessions. This project was inspired by a creative writing prompt featured in a YouTube video (https://www.youtube.com/watch?v=zAY5c21EEBU). LK was invited to use 3D drawing tools to accurately portray a virtual floating city while maintaining the reality and physics of the real world. In this spontaneous, collaborative, brainstorming activity, LK demonstrated an ability to effectively convey, using domain-specific language and multimodal forms of linguistic expression, the purposes of his multidimensional illustration (see Figures 3 and 4).

Figure 3: Screenshots[5] of LK explaining to HK (graduate student) the design of the floating garden in the "City in the Sky."

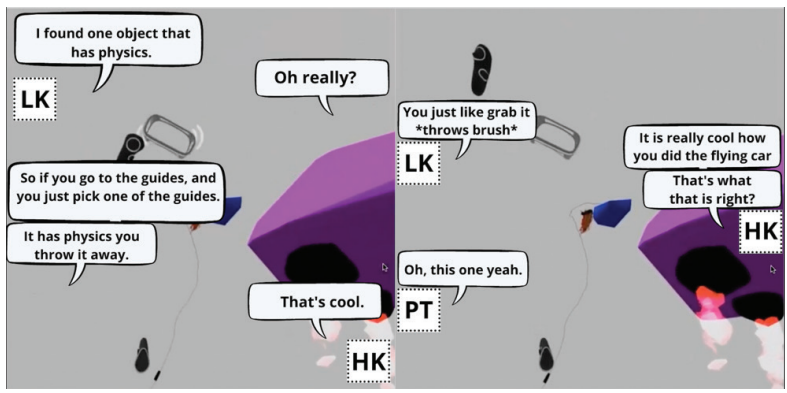

Figure 4. Screenshots of LK mentioning physics to HK (graduate student) and PT (undergraduate student) while constructing the "City in the Sky."

Throughout the "City in the Sky" sessions, LK played and communicated using drawings, space, and perspective in an embodied manner (the "embodiment" factor in our model). An example of how LK was able to use his body and space to manipulate his virtual environment is shown in a YouTube video clip (https://www.youtube.com/watch?v=-8GCktZsckQ). In Figure 3, LK's avatar, which is represented by a white rectangular outline of a headset, is seen facing a garden in the imagined city. The image was captured during his explanation of the layout of the crops as he uses his hands to trace the shape of corn stalks, which reflects a communicative gesture coordinated with his verbal explanation, hence providing an example of how multiliteracy is mediated by embodiment.

LK added to his drawing from a bird's eye view and at times would alter his perspective by zooming in closer to be proximally level with his drawings. He also expressed an awareness of real-world hazards that could potentially harm the city and those within the airspace. Communication in spatial terms seemed to convey a shared understanding among all members of the session; when one of the graduate students stated "over there," LK immediately turned around to look at the houses they were referring to within the virtual space. Such indexicality shows LK's spatial awareness and memory association with his constructed environment, and demonstrates how communication can be distributed across language and space (hence the "presence" factor in our model).

Later within this same session, LK came up with an idea for a farm in his city to use methane as the primary form of energy to power up the farm and grow produce. LK's previous knowledge of how energy works seemed to complement the "City in the Sky" prompt; he had mentioned this particular interest in science class at school in previous sessions. Allowing for such connections to personal interests seemed to inspire LK to integrate some of the scientific concepts he was learning in his MultiBrush creations. As such, it seems that a simple prompt can inspire learners to engage in scientific thinking as well as artistic thinking, while simultaneously being engaged and co-present in a virtual environment with other IVR users.

Key pedagogical goals guiding our sessions are first to connect young and near-peer (undergraduate) co-learners through a collaborative interaction that promotes learning, and second, to allow time and opportunities for creation and reflection in VR. Throughout the "City in the Sky" session, there was an authentic and organic balance of quiet and talkative moments, which seemed to allow all members to think about what they were creating together, while also having plenty of opportunities to ask questions and make comments to keep LK engaged ("sociocultural interaction" factor in our model). For example, LK was able to draw from his background knowledge on how crops may grow, such as which crops can grow at high altitudes, and to incorporate this knowledge into his drawing. He was able to practice urban planning in a VR context and bring in knowledge from other non-VR games he engages with on his own, such as Minecraft, in which farming plays a large role in developing the Minecraft world.[6] As LK was drawing his crops, the undergraduate researchers were also researching crops that could survive at similar altitudes and temperatures. This collaborative pedagogy might also help to facilitate future sessions with multiple participants, and will help us to understand the thought process behind the decisions learners make without disrupting it.

To take advantage of the sense of agency afforded by IVR, we positioned our young participants as co-researchers who led the design thinking and use of

applications and tools. In one particular session, three undergraduate research assistants were new to VR and had never tried MultiBrush before. LK helped to guide them on how to use the application and shared tips. He also taught the research assistants a trick he just realized he could do in MultiBrush. LK was positioned as the lead architect on the "City in the Sky" project, and the research assistants were the team of engineers assigned to work on the project. Positioning LK as the meaning-maker in the virtual interactions gave him agency in a way that they felt online school normally does not: "online school is repetitive—especially online where you do the same thing every day." Using technology does not automatically result in better learning, but if VR is used mindfully along with pedagogical techniques that encourage agency, together they can aid the learning process by allowing students to express themselves and take more of a leadership role.

LK's "City in the Sky" sessions seemed to demonstrate four of the potential affordances of IVR that were discussed earlier, namely, Dalgarno and Lee's (2010) theoretical proposal and Makransky and Peterson's (2021) CAMIL model. In our project, research facilitators focused on fostering our young co-researchers' agency at all levels of a given IVR session. From learning activities to session topics, the youth were encouraged to freely choose what they wanted to do, and as facilitators we immersed ourselves alongside their creative projects involving imaginative and unlimited storytelling. For instance, LK previously stated that he was interested in learning about space and STEM-related topics. Therefore, we chose a video prompt that instructed LK to create a "City in the Sky" using the skills and knowledge that he has learned, in order to translate it into this problem-solving/storytelling project. Additionally, LK had the opportunity to create this project alongside researchers who assisted in forming his ideas within a shared MultiBrush space. The collaborative learning process within IVR provides avenues for students to share their ideas, removes the barrier of traditional learning spaces, and provides the opportunity for students like LK to tackle the project by sharing their ideas and letting the researchers do the same. Without this barrier, LK can virtually experience being in and exploring the power of embodiment within IVR. The IVR affordances can take students beyond the limitations of resources provided by traditional education and allow them to consider real-life applications without those limitations.

Another IVR app/tool that we used with our participants to explore and exchange narratives about different places is Wander. Wander is a VR application that allows users to visit various locations around the world using 3D 360-degree Google Street View locations, and to have an IVR experience with other users simultaneously or individually. Wander allows users to "walk" around the Google Street View images and explore the world with ease and comfort

using a VR headset. It also allows users to transport themselves around the world and through time with the option to view previous Street View images throughout the years. LK chose the Golden Temple in India to explore, because he had learned about it in class. We also utilized Wander's "random location" tool and asked LK to use clues, such as languages on signs or plant life, to guess where he was in the world. Our approach is to leverage VR affordances by immersing players in a rich context for language use that involves embodied interaction and contextualized gameplay. As such, we invited players to relate to literacy in a different way and expand the possibilities for play, expression, and communication.

Similarly, in a session with a multilingual adolescent, Nicholas Cooper (a 16-year-old multilingual learner with a Latinx/Chicanx background who identifies as male and uses he/him pronouns), we used a web-based geographic discovery game called GeoGuessr, which uses existing Google Street View data and allows its users to guess where they are based on geographical cues and at times languages. Since our participant is multilingual, we were able to conduct portions of the session in both Spanish and English. This was especially useful when we had a round in which we were trying to identify and locate the Sagrada Familia basilica in Barcelona, Spain. Nicholas and his fellow participants used context clues such as signs in Spanish along with the Euro symbol to quickly identify that it was indeed Spain. The affordances that GeoGuessr provides allow for multilingual participants to expand their multiliteracies beyond their immediate surroundings, and use their knowledge and experience to help identify geographical clues and learn about various locations across the globe.

In summary, the apparent success, defined broadly as observed positive productivity and expressed perspectives of our participating youth, of our young co-researchers' activities may be due to the fact that careful attention was paid to both "media and method." The deliberate design of activities, selection of appropriate games and apps, and our encouragement of free exploration and integration of particular interests together seem to provide the necessary network of resources that fostered the invested interest of the participating youth.

4. Conclusions

Our conceptual article is an attempt to theorize important cognitive and linguistic affordances of IVR technologies for learning, and in particular, for the development of multiliteracies. It adds to the growing body of research about IVR, which could benefit from such theoretical insights needed to advance research efforts on specific multimodal affordances of IVR and key pedagogical approaches for supporting multilingual learners. We presented specific

examples of IVR sessions with adolescent bilingual learners recruited through our university-housed reading clinic, in order to make visible the particular affordances of embodied cognition, presence, agency, contextualization, and collaboration through IVR. We also suggested a model for researching multiliteracies based on Makransky and Petersen's (2021) CAMIL as a foundation for building a working theory of learning via IVR (Figure 1).

Future work will involve a thorough and principled analysis of our database, where we hope to highlight the importance of creating opportunities for learners to develop a sense of agency, so that they feel empowered to leverage the immersive, embodied nature of IVR for creating multimodal artifacts and stories. Such agency may be realized through the engagement of participants' interests and active collaboration, and further sustained by the immersive engagement that is not possible with traditional media.

The multidimensional, multimodal spaces provided through IVR technologies serve as a potentially prolific context for exploring key issues for multilingual learners, particularly in the area of translanguaging in collaborative learning spaces. Our future research on the affordances of IVR will seek to inform second language acquisition theories by investigating how emerging multilingual learners are no longer "users as decoders of language," but rather "users as designers of meaning" (NLG, 1996, p. 74). There is a need for more research on multilingual users' multimodal forms of meaning-making, as the limited literature on second language education indicates (Dagenais et al., 2017; Tan et al., 2020). Planned work will involve building on the theoretical offerings presented here, with the goal of clarifying the ways in which K–12 schools and HE can benefit from incorporating new IVR technologies for engaging learners in multimodal literacies in an increasingly multilingual society. Other areas for future research include factors that affect learning, such as cognitive load and motivation, and a more in-depth look at the limitations of IVR and their impact on pedagogical design.

Acknowledgments

We would like to thank our adolescent participants and their families, and the undergraduates and the development team who were involved with the project.

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Notes

1. Some studies use VR to refer to 3D virtual environments viewed on a computer screen, which is a different experience from immersive VR environments, which are viewed through head-mounted systems (Ma & Zheng, 2011; Slater & Sanchez-Vives, 2014). In this conceptual study, we refer specifically to fully immersive VR using headsets and hand-held controllers.
2. We add a note of caution about the need to get users onboard in a way that will not overwhelm them; that is, to encourage them to use prior knowledge

of games and app navigation to help them understand the physics or spaces within VR, and to help them reflect on what they are experiencing (what is happening to them, such as haptic feedback, sensory and auditory experiences, etc). It is also necessary to tell users ahead of time that they might feel nauseous, and if they do, they can simply take the headset off.

3. Our participating youth were given full license to create their own pseudonyms.
4. A participant plans strategy with other players before starting an adventure game in Rec Room (top left); real-world panoramic photos taken in a museum (top right) and the ISS (bottom right) seen in Wander; and an overhead view of an amusement park co-created by a participant in MultiBrush (bottom left).
5. Both images (in red) depict a floating garden that grows "root vegetables" using heat from recaptured methane emissions from landfills (left, represented as blue bubbles), in order to offset the colder temperatures at high altitude. The methane is "trapped" and "condensed" by a tank (right, in blue), from which a "line … spreads the warm gas (right, in translucent yellow) on top of the plants." Using his hands to visually trace the shape and layout of the plants, LK moves vertically along the asparagus (right, in green) and horizontally to show corn and melons (not pictured, obscured by black wall).
6. The learner's use of previous knowledge from playing Minecraft suggests that gamers have many skills and a direct understanding of the physics of VR environments and possibilities for interaction. Gaming could be considered as a form of literacy and counted among multiliteracies that are to be developed.

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