



Personal Spaces and Communal Consequences: Navigating Geographical Tensions With the Socially Responsible Behavior through Embodied Thinking (SORBET) Project

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Specialty section:

This article was submitted to
Virtual Reality and Human Behaviour,
a section of the journal
Frontiers in Virtual Reality

Received: 27 January 2022

Accepted: 03 March 2022

Published: 24 March 2022

Citation:

Lim KYT and Li SCX (2022) Personal
Spaces and Communal
Consequences: Navigating
Geographical Tensions With the
Socially Responsible Behavior through
Embodied Thinking (SORBET) Project.
Front. Virtual Real. 3:863615.
doi: 10.3389/frvir.2022.863615

The COVID-19 pandemic has impacted societies in different ways. This variation is inherently geographical with patterns across space and time reflecting underlying societal inequalities. This study describes a learning intervention designed to afford participants opportunities to experience the diffusion of a (virtual) virus within a community, albeit in a safe way. The intervention was enacted in March 2021 among nine undergraduate teachers-in-training at a teacher-education institute in Singapore. Participants were invited to reflect on the connections between their personal decision-making and its impact on the broader community, after having first undertaken a collaborative task in a virtual environment. The Socially Responsible Behavior through Embodied Thinking (SORBET) Project draws on the learning sciences in terms of embodied cognition and projective identity, and in this study, seeks to apply them to geographical understandings of diffusion. Responses from post-activity interviews are reported along three themes, as structured by the cultural-historical activity theory. Through encouraging reflection on authentic experience, the authors hope to catalyze a more grounded appreciation of the need to practice positive social habits in the context of a pandemic and by extension, contribute to the fight against the virus through the application of geographical thinking at local and global scales.

Keywords: geography, novice intuitions, social responsibility, COVID-19, embodied cognition, cultural-historical activity theory

INTRODUCTION

Mansilla and Gardner (2009) have written in “Disciplining the Mind” that “all disciplines embody distinct ways of thinking about the world”. As a broad academic discipline encompassing the seemingly polar physical and human aspects of the world, universities divide researchers within the discipline of geography into smaller departments such as earth science and urban studies, each characterized by distinct organizational constructs. The split between various sub-disciplines in geography suggests a schism in their respective epistemologies. Despite this, the multiple branches of geography can collectively acknowledge their membership in the said discipline because geographers can agree on a primary concept governing geographical thinking, namely space. Subject matter knowledge pertaining to geography helps individuals make sense of the space surrounding them and



FIGURE 1 | Avatars encroaching in to safe-distance.

their environment. Lambert (2017) has described this as thinking geographically, which is very useful for individuals to navigate and analyze their surrounding phenomena.

With the onset of the COVID-19 pandemic, the world has been forcibly introduced to an entirely new disease. Consequently, a new need has arisen: To nurture among individuals the appropriate dispositions of social responsibility, thereby mitigating diffusion of the pandemic.

This study describes an intervention in which the authors seek to do so in the context of geography, by appropriating an approach to designing learning activities. This approach—the Socially Responsible Behavior through Embodied Thinking (SORBET) Project—was originally enacted in July 2020 (Lim et al., 2020). This study first outlines SORBET, and then presents a review of related literature discussing the theories that ground the design of the SORBET approach. This is followed by a description of the methodology adopted and a discussion of the findings. The article concludes with reflections and recommendations.

DESCRIPTION OF THE SOCIALLY RESPONSIBLE BEHAVIOR THROUGH EMBODIED THINKING APPROACH

SORBET is an approach to designing for learning that seeks to surface learners' intuitions about appropriate social behavior, for subsequent dialogue among peers and their teacher. SORBET is

designed as two complementary halves—embodied and dialogic. During the first half, participants interact within a virtual environment during which—unbeknownst to them—a virtual virus is being diffused. For each enactment of SORBET, the activity tasked to the learners should be carefully customized by the teacher as an authentic task. These tasks can be customized to a variety of disciplinary domains and learner cohorts; examples include a treasure hunt for lower grade levels, and a mapping activity for students of geography. As participants interact in the environment, discs of 1-m radius (to scale with the avatar) will momentarily appear from time to time around their avatars. These discs are color-coded depending on whether another avatar is encroaching within the safe radius. An example is shown in **Figure 1**.

During the second half, participants are able to access records of their respective interactions (from the first half) and view how the (virtual) virus diffused within their community over time. Peer discussion during this half can be facilitated by a teacher, in order to consolidate the learning points arising from the embodied activity, such as reflection on the consequences of one's personal decision-making and behaviors upon the community as a whole. It is these latter conversations around beliefs and values—and not so much the outcome of the preceding embodied task itself—that are the true focus of the SORBET approach.

From a technical standpoint, the approach can be applied to any platform of virtual environment which supports the exporting of data to an external database. For example, in the

study described in this article, the platform was the open-source version of Second Life, namely, OpenSimulator (OpenSimulator, 2020; as an aside, more recent iterations of SORBET are enacted in a bespoke application developed using the Unity game engine).

REVIEW OF LITERATURE

Cultural–Historical Activity Theory

The theoretical framework which undergirds the present study is the cultural–historical activity theory (CHAT). The roots of CHAT or Activity Theory—as it is commonly referred to—have been traced back to the Soviet Union in the 1920s as part of the socio-historical school of Russian psychology. The basic foundations of CHAT can be credited to Russian psychologists such as Vygotsky, Leont’ev, and Luria, for laying insights into the dynamics of thought and consciousness. Basically, the premises of their arguments arose as a response to the need for transcending prevailing understandings of psychology, child development, and learning studies that were then dominated by behaviorism and by psychological theories, both of which they regarded as individually oriented rather than socio-culturally oriented. As a result, they sought to go beyond the individual-centric perspective and into the socially inclusive perspective.

The first generation of CHAT is considered to have emerged from Vygotsky’s theory of cultural mediation. Cultural mediation was conceptualized as a response to behaviorism’s explanation of the development of human mind or consciousness, which was seen as reducing the human mind to a series of “stimulus—response” processes associated with underlying biological molecular components or structures of the brain. To Vygotsky (1978), this explanation was not sufficient to fully explain the complexity of human relationship in a social context. In his view, consciousness emerges from human activity mediated by artifacts (tools) and signs.

Vygotsky designed a triangular model which embodied the idea of semiotic mediation between subject, object, and mediated artifact. In the triangle, which featured the subject, object, and mediating artifact triad, the subject, object, and artifact formed a dialectical relationship, whereby each affected the other and the activity as a whole.

In the Vygotskian framework, the unit of analysis was primarily the individual. For this study, a more collective model of CHAT is used instead of the individualistic model of first-generation CHAT.

The second-generation CHAT attempted to move beyond Vygotsky’s individually focused model to a collective model. In Engeström’s (2014) graphical depiction of the second-generation CHAT, the unit of analysis was expanded to include collectively motivated activity toward an object, thus creating a window into understanding how collective action by social groups mediates activity. With this model and the inclusion of community, rules, and division of labor, the second-generation CHAT afforded a new level of understanding and analysis of the interactions between the aforementioned elements, in both individual and collective units of analysis. Compared to first-generation CHAT, Leont’ev’s (1981)

second-generation CHAT was more focused on and useful in understanding the mediational effects of systemic organization of human activity.

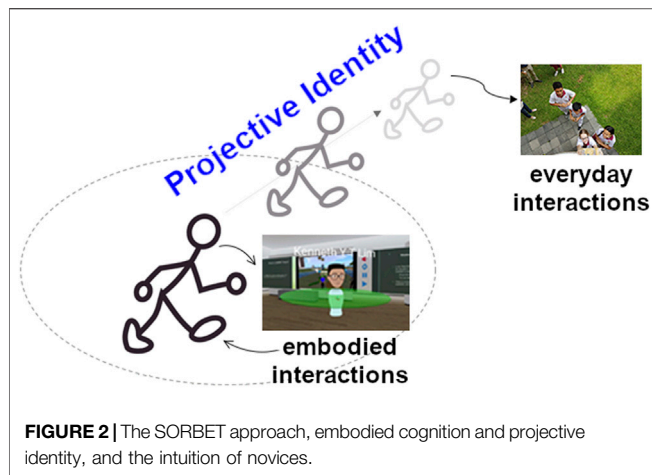
The implications of second-generation CHAT is that activity only exists in relation to rules, community, and division of labor, and the unit of analysis for studying human behavior is expanded from that of individual activity to a collective activity system. In the analysis, the collective activity system includes social, psychological, and cultural perspectives of the organization of belonging. Engeström has argued that in this conceptualization, context or activity systems are inherently related to the deep-seated material practices and socio-economic structures of a given culture. Along this line of argument, Leont’ev perceived that thought and cognition should be understood as a part of social life—as a part of means of production and systems of social relations on one hand, and intentions of individuals in certain social conditions on the other.

CHAT therefore centers around three main ideas, namely that humans collaborate, learn by doing, and communicate in and *via* their actions; humans make, use, and adapt tools of all kinds to learn and communicate; and community is central to the process of making and interpreting meaning—and thus to all forms of learning, communicating, and acting (Leont’ev, 1981; Vygotsky, 1978). SORBET aligns well with the CHAT as the former is a discipline-neutral approach that foregrounds the development of values through communal action within a virtual environment.

Together, CHAT is a theoretical framework for studying how humans can purposefully transform natural and social reality, including themselves, as an ongoing culturally and historically situated, materially and socially mediated process (Roth and Lee, 2007; Roth et al., 2012). The components of CHAT that guide the SORBET activity design will be discussed later in this article.

Dispositional Change and Embodied Cognition

The embodied nature of the first half of the SORBET approach finds its theoretical roots in Gee’s (2003) notions of projective identity. He has described how well-designed game-based environments potentially develop a learner’s projective identity, which combines elements of both the learner’s atomic (human) identity and the virtual (avatar) identity. These projective identities can sustain beyond the game environment to influence values and behaviors in other contexts. In a well-designed virtual environment, learners are also able to feel a strong sense of presence. Presence refers to the feeling of being in an environment (Steuer, 1992), such that one experiences the stimulated physical environment despite the physical body not being located in that reality (Sanchez–Vives and Slater, 2005). A strong sense of presence is crucial to effective learning because it affirms that the virtual environment is a real and relatable space. Classical Kantian views of geographical knowledge believe that space governs all disciplines because all historical phenomena are delimited by the geographical spaces in which they occur (Cresswell, 2013). Enduring understandings in learners will thus be reinforced if the



learners generate knowledge in a relatable space. While initial conceptions of space were largely limited to physical space, geography as a discipline, has evolved over time to extend the concept of space beyond the physical characteristics (Soja, 1989; Lefebvre and Nicholson-Smith, 1991; Thrift, 2003; Gregory et al., 2011). The SORBET environment extends the logics of spatiality into the virtual world (Batty, 1997; Gordon, 2008), using virtual reality as a safe platform for learners to formulate the relationship between the virus and interpersonal space.

Mahon (2015) and Clark (2017) developed embodied cognition as an extension of Vygotsky's (1978) and Gibson's (1979) works. Embodied cognition can be thought of as the involvement of multiple senses for enriching immersion and understanding (Clark, *ibid.*; Mahon, *ibid.*). Shapiro (2019) has further elaborated that embodied cognition consists of three themes: conceptualization, replacement, and constitution. Conceptualization refers to the subjectivity of understanding the virtual world. It is primarily influenced/limited by the individual's self. Replacement—a more psychology-specific term—refers to embodied cognition following a non-standard understanding of cognitive science. Lastly, a constitution is translated to the body or world that plays a constitutive rather than a causal role in cognitive processing. Essentially, embodied cognition can be understood as the body and senses acting not as peripheral components of our thinking, but instead as parameters that affect one's thinking concerning one's material environment, situation, and timing (Barsalou, 2010; Shapiro, *ibid.*). Additionally, literature in the field of neuroscience corroborates this understanding of embodied cognition. For example, research has shown that emotional impulses are transmitted directly to the amygdala and the insula, leading to actions in the motor system (Ratey, 2001). **Figure 2** illustrates the preceding discussion.

In earlier work (Lim, et al., 2020), the authors have attempted to describe the aspects of the relationship between CHAT and embodied cognition thusly, “Mediations at both the individual and social levels involve thought, action, and emotion. The three form mutually complementary facets in understanding learning. In this framing, meanings are appropriated through such mediations. Emotion is an integral part of the experience from which subsequent

meaning-making is based”. We see this trilectic coupling as key to surfacing a learner's intuitions (Lim, 2015).

For the present study, we were interested in surfacing participants' intuitions about social distancing. This is because exhortations to practice social responsibility have been met with various degrees of compliance, and—even when social distancing protocols are observed—it is not easy to determine the extent of ‘buy in’ of the need for heightened social responsibility.

Intuitions are tacit by definition. It is not possible for an instructor-figure to explicitly interrogate learners about their respective intuitions. Our previous work has suggested that one way to surface learner intuition for subsequent peer-based dialogue is through the design of learning tasks which have a purportedly different curricular objective instead (than the intended objective of surfacing learners' emerging and nascent understandings). If well-designed, such tasks can surface learner intuition as learners let their guard down as they are engaged in attempting to attain (what appears to them as) the goal. The authorial team has a track record of working with teachers in the design of such tasks since 2009 (Lim et al., 2022).

Research Question

The diffusion of any given disease—COVID-19 or otherwise—is inherently spatial. The research question that guided the present study was therefore:

How might foregrounding the spatial nature of a given task catalyze discussions around the contestation of personal space, individual decision-making, and subsequent consequences to the community, in the context of virus diffusion?

MATERIALS AND METHODS

Nine student-teachers from the National Institute of Education (NIE), Singapore, were recruited through convenience sampling to participate in this research.

From the preceding discussion on designing for the surfacing of intuition, the authors decided that, given the focus of the research question, a suitable design of task and research would be an activity in which the participants were obliged to interact collaboratively in a spatially related task to achieve a common goal. It would be through the necessity to interact collaboratively (as their avatars) that the (virtual) virus would have the opportunity to be diffused among the participants' respective avatars.

Task Design

As stated in a preceding section, the diffusion of any given disease—COVID-19 or otherwise—is inherently spatial. After some consideration, it was decided that a *Hashiwokakero* activity would afford a sufficiently embodied and authentic task to these teachers-in-training. *Hashiwokakero* is a puzzle game developed by the Japanese publisher Nikoli (Andersson, 2009). As described by Coelho et al. (2019),

The puzzle is played on a rectangular grid with no standard size. Some grid cells contain a circle, called an island, with a number inside it ranging from one to eight. The remaining positions of the grid are empty. The player must connect all

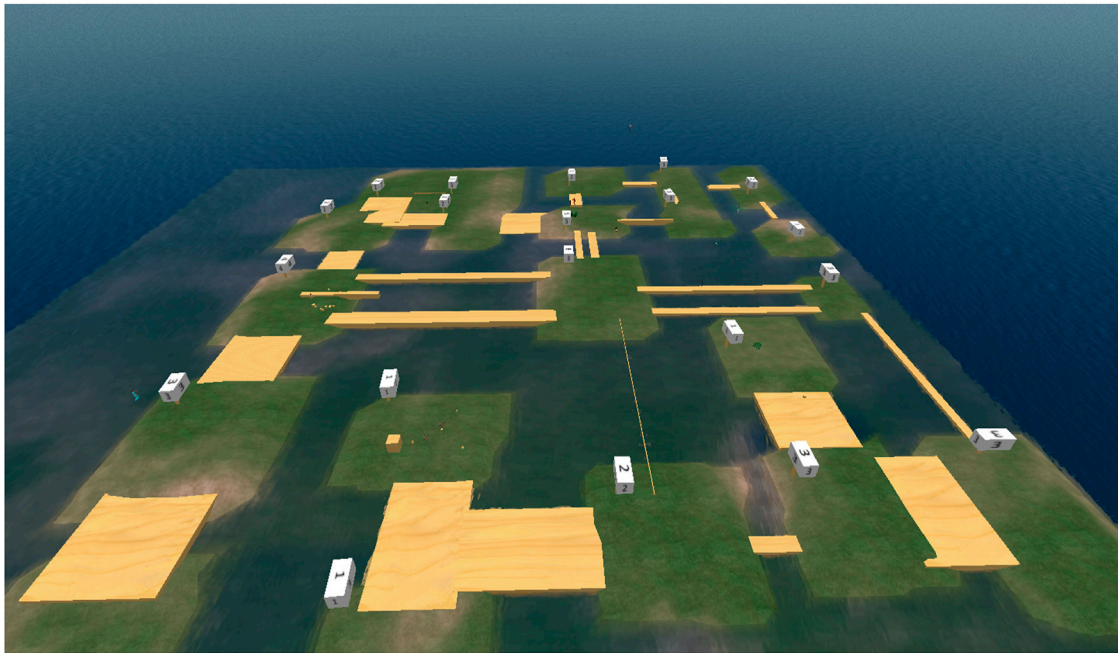


FIGURE 3 | Overview of SORBET environment showing similarity to *Hashiwokakero*.

the islands by drawing bridges between them. The solution to the puzzle must respect the following rules:

- The bridges must begin and end at distinct islands.
- They must not cross any other bridges or islands.
- They may only run horizontally or vertically.
- At most, two bridges may connect any pair of islands.
- The number of bridges connected to each island must be equal to the number inscribed in the circle.
- Each island must be reachable from any other island.

Although originally conceptualized as a mathematical puzzle, it should be clear from the preceding description that *Hashiwokakero* has implicit spatial elements (such as the bridges and islands, and the layout thereof). This very nature of *Hashiwokakero* lends itself to a geographically themed activity, especially one which is enacted within a virtual environment.

Likewise, *Hashiwokakero* was initially designed as a single-player puzzle game. By re-imagining it as a multiplayer activity within an immersive environment which affords concurrent participant interaction through their respective avatars, elements of potential conflict, encroachment, and negotiation are introduced, which, in turn, provide authentic opportunities for communication, collaboration, and co-construction.

Furthermore, the elements associated with *Hashiwokakero*, such as its rules and division of labor, not only provide game-like constraints which circumscribe and oblige participants' interaction with each other, but they also align well with the various elements of the cultural–historical activity theory. Specifically, these alignments among *Hashiwokakero*, the SORBET approach, and the elements of CHAT are as follows:

- Tool: The embodied-dialogic nature of the SORBET approach.
- Subject: Each participant (or each student, if SORBET were enacted in a classroom setting).
- Community: Participants as a whole, within which the (virtual) virus is being diffused.
- Object: To complete the *Hashiwokakero* puzzle by building bridges to connect the islands in the virtual environment.
- Rules: The rules (stated in preceding paragraphs) of the *Hashiwokakero* puzzle.
- Division of labor: The division of the responsibility as participants decide and negotiate among themselves how to approach building bridges in a manner congruent with the rules of the puzzle.
- Outcome: To nurture values of social responsibility among participants

Figure 3 below shows the virtual environment used in the intervention, including bridges connecting the islands. **Figure 4** shows the perspective of the environment, at the scale of the avatar.

Research Design

A qualitative interpretivist paradigm was selected as the approach to this study. “Qualitative research is understood to denote inductive, generative, constructive, and subjective processes” (Preissle and Le Compte, 1984). Given operational constraints described later in this article under “Limitations”, the only practicable method which presented itself to explore the research question was to interview the student-teachers after they had participated in the *Hashiwokakero* activity through the SORBET approach.

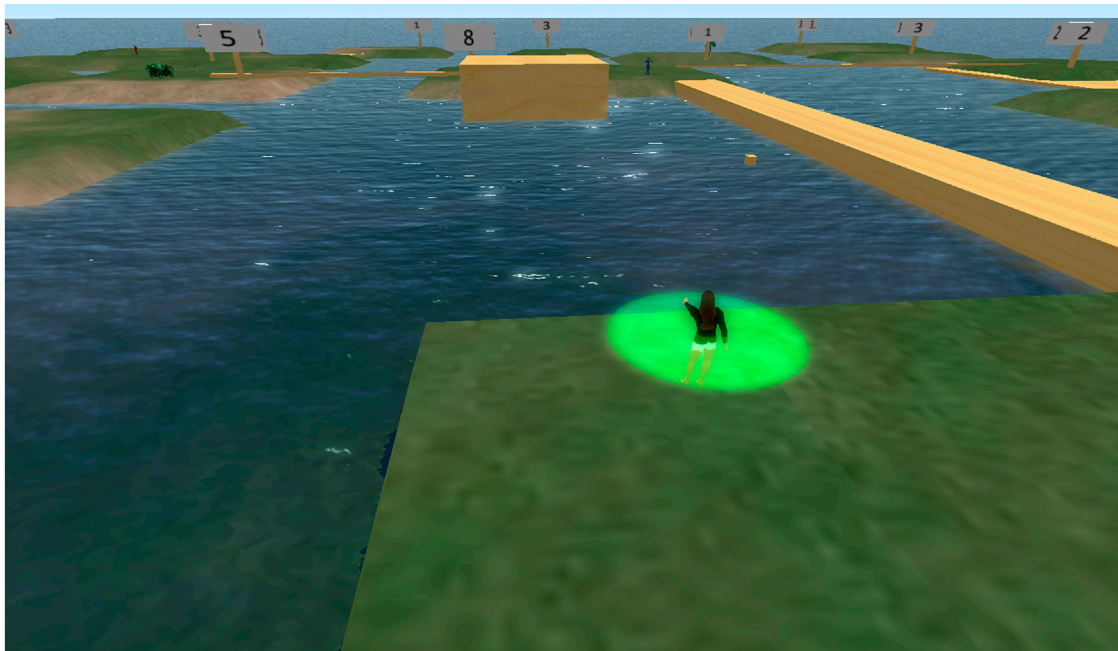


FIGURE 4 | SORBET environment from the perspective of one avatar.

TABLE 1 | Participant profile by academic discipline.

Participant	Academic discipline
A	Biology
B	Music
C	Geography
D	Music
E	Geography
F	Geography
G	Geography
H	Geography
I	Physical Education

As stated earlier, nine student-teachers from a teacher-education institute in Singapore were recruited to participate in this research (a 10th member was not able to participate due to urgent commitments). This study will refer to the student-teachers henceforth using the letters from A to I. The participants were recruited *via* convenience sampling through the second author's personal social network. Fellow student-teachers were selected as these individuals are trained to be more sensitive and aware of the learning sciences and theories of cognition, with the assumption that this training would allow them to articulate their reflections about participating in the intervention more comfortably. Among the nine participants, five were undergoing training to be geography teachers, with the remaining four being trained in other disciplines. **Table 1** provides an overview of the participants in terms of their respective academic domains.

The rationale behind this choice was to ensure that the interview responses would not be biased towards a particularly geographic epistemology.

After the SORBET activity, the participants were interviewed. The interviews were semi-structured to allow for greater freedom of responses from interviewees while simultaneously retaining a structure or guidelines for the researcher to follow (Barriball and White, 1994), thus ensuring that the data collected remained relevant. The interviews sought the respective opinions of each participant regarding the SORBET approach, particularly about whether the SORBET approach afforded them opportunities to ground their emerging understandings about virus diffusion within the context of geography.

Data Collection

Data collection spanned 2 weeks, over March 2021. The nine participants were first invited to a classroom within the teacher-education institute. Before starting the *Hashiwokakero* activity, participants were given a 10-min familiarization on the user interface of the virtual platform, in order that they might have some proficiency in navigating the virtual environment and laying out bridges. For the next 20 min, they participated in the *Hashiwokakero* activity as structured by the SORBET approach, facilitated by their peer—the second author. The dialogic half subsequent to that of the approach was 30 min in duration, giving a total of 1 h for the entire session. This process was recorded *via* audio and video methods. The voice recording was immediately transcribed with the help of transcription software on the same day. Additionally, pictures of the classroom layout and screenshots of the virtual environment

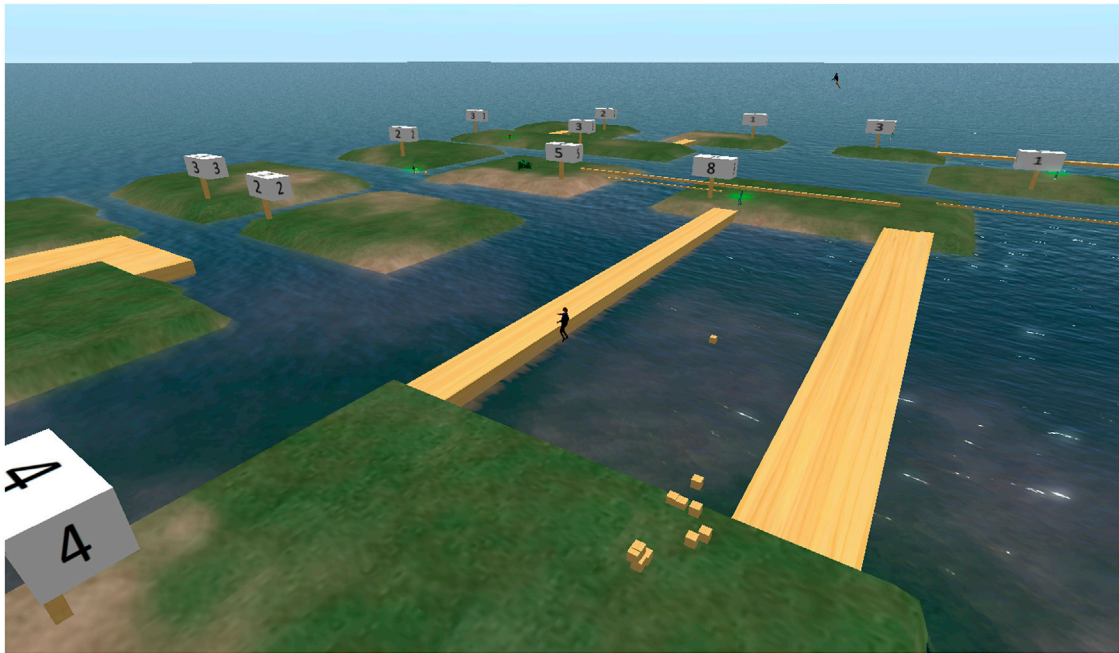


FIGURE 5 | Hashiwokakero activity in progress.

Simulation Summary

9 students connected. Simulation complete. [Final Report Refresh](#)

Initial Cycle 1 Cycle 2 Cycle 3 Cycle 4 **Cycle 5** Settings Restart

Infection Condition: 7 (Probability: 6/36 = 16.670000%)

Participant Status

Click a participant to view their detailed log. Participants highlighted in red are infected as of the current cycle.

SORBET a46	SORBET a45
SORBET a43	SORBET a49
SORBET a41	SORBET a47
SORBET a42	SORBET 48a
SORBET a44	

FIGURE 6 | Post-simulation summary of infected/non-infected participants.

as the bridges were being negotiated and built would be taken from time to time, capturing evidence of the progress of the co-construction. Finally, one-to-one interviews were conducted with participants within 2 weeks of the SORBET learning activity. Participants were invited to be interviewed over a

Zoom meeting to maximize their safety given prevailing safe management protocols. Interviews typically took place over half an hour each, and were recorded and transcribed immediately. Member checks (Lincoln and Guba, 1989) were carried out with the respective transcripts.

RESULTS AND DISCUSSION

At the end of the embodied half of the SORBET approach (the *Hashiwokakero* activity), all participants were given access to the interaction data and infection data through a common dashboard. It was discovered that over the 20 min, there was one instance of successful infection by the (virtual) virus from one avatar to another. **Figure 5** is a screenshot depicting the virtual environment during the *Hashiwokakero* activity.

Figure 6 is a screenshot from the data dashboard accessed by participants during the dialogic half of the SORBET approach:

The authors were somewhat disappointed that there was a single instance of successful infection, even though the participants—through their avatars—had been in proximity with each other from time to time as they negotiated and co-constructed the bridges. Nevertheless, because the participants were teachers-in-training participating in what was to all intents a micro-teaching session as facilitated by their peer, they were able to appreciate the intent of the activity, as evidenced in their considered responses during their respective interviews. These responses are discussed in the following sections, with respect to cultural-historical activity theory (CHAT), specifically to “subject”, “tool”, “object”, “community”, and “outcome”. As described earlier, the alignments among *Hashiwokakero*, the SORBET approach, and the elements of CHAT are as follows:

- Tool: The embodied-dialogic nature of the SORBET approach.
- Subject: Each participant (or each student, if SORBET were enacted in a classroom setting).
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Responses in Terms of the Subject-Tool-Object-Outcome Axis

In terms of the Subject-Tool-Object-Outcome axis of the intervention, participants described how particular affordances of the SORBET approach facilitated the linkage from the virtual activity to real-life contexts (emphases authors’).

Participant A: My understanding of the geography of health and diseases was greatly reinforced after using SORBET. Although I do not have very detailed knowledge and insights into the geography of health and diseases, I do have a general understanding of what the topic entails. This general knowledge and understanding were concretized after using the SORBET, as it provided a clear and interactive example to elicit the spread and

transmission of diseases. It illustrated certain scenarios that occur in real life such as the different vulnerabilities of people to a certain disease and an understanding of how the nature of specific disease transmission can inform us about the measures, we can take to prevent further transmission.

Participant B: Using SORBET really provided an immersive experience that showed me (through engagement) how quickly diseases could spread within a community. While many of us learn of such things by visiting case studies and looking at it from a theoretical perspective, being able to play the game, and experience it for ourselves was definitely a bonus.

Participant C: Personally, I think through the game, concepts such as proximity is elicited as seen in how those we came into contact with physically in the game caused some of us to be infected by the virus. Transferring this idea to the real world, we can see the importance of social distancing in today’s context where COVID-19 has taken the world by storm. Moreover, the global scale of this pandemic has made me understand how individually, we all have a part to play in combating this virus together by abiding by the rules set in place by authorities.

With reference to the literature reviewed in a preceding section of this article, these points articulated by participants A, B, and C implicitly reference-embodied cognition and projective identity. The excerpts affirm the usefulness of the CHAT framework as analytical lens in the context of the SORBET approach, regardless of the individual’s professional training in the discipline of geography. It can also be observed that given sufficient time to reflect, individuals may contextualize the disease at different scales (Participants A and B think of the severity of the virus within their immediate environment, while participant C’s epistemological utterances suggest greater fluency navigating local and global scales). Hence, the activity does not prescribe any subject knowledge to the participants, instead allowing them to feel socially responsible through their understanding of the embodied experience.

One participant D, also noted that he did not find the virtual environment useful in conceptualizing a response to the SORBET.

Participant D: However, apart from learning how diseases spread and the randomness or probability of a virus spreading in the virtual environment, this SORBET activity was not that helpful in explaining how to prevent these diseases from spreading.

Participant D’s response emphasizes the necessity for the second half of SORBET—the dialogic discussion led by the facilitator. As participant D highlighted, the virtual environment attempts to catalyze understandings of the virus but does not present any solution to the students. Instead, only when teasing out opinions during the class discussion, teachers can better facilitate the consolidation of the various embodied experiences of students and draw them toward thinking about socially responsible solutions that they feel sufficient agency to transform their respective local environments personally.

Responses in Terms of Interpretations of the Object

In terms of the CHAT framework, the opinions of participants toward the nature of the object (the *Hashiwokakero* puzzle) were diverse. Participants would try to link their initial experience of building bridges to certain elements and concepts in geography. These include ideas

such as space and urban planning, which emerged when they were asked which geographical topics they felt the activity might relate to.

Participant C: Most definitely. I think one topic that I thought of was urban planning. This could be seen in how we had to strategically place our bridges such that we meet the quota stated on each island.

Participant E: It certainly has some relationship with geography because we were spatially far apart in the SORBET world. Furthermore, geographical location is very important in communicating with each other to effectively build bridges.

Participant F: I think the open world concept without a map taught us the importance of creating landmarks in which we can take reference to as our “north”.

However, while six out of the nine participants felt that *Hashiwokakero* activity had some relationship to geography and that there were geographical approaches that could help in working together to solve the puzzle, to varying degrees, all participants expressed a degree of dissonance and/or discomfort that the disciplinary connections were not more explicit.

Participant G: I think the theory intended was urban planning of some sort but it felt a little arbitrary. Just because I put connectors between areas does not mean I have technically learned anything about urban planning.

Participant B: I felt that the activity did have some grounds in geography (urban planning etc.), although it could have been slightly more firmly grounded. It was definitely enjoyable as we were engaged in problem-solving activities while being surrounded by a gaming experience that allowed for collaborative learning with others.

Participant D: It would be grounded in geography if there was a topic tied to the activity of building bridges, maybe about landforms possibly? Otherwise, it would probably be a math problem-solving puzzle where we need to figure out how to get the correct number of bridges.

This diversity of interpretations is not too surprising, considering that the *Hashiwokakero* puzzle originated as a mathematical (and not a geographical) puzzle. Previous studies (author, et al., 2020) have shown that the SORBET approach is effective in catalyzing dispositional change when the activity is authentic to each particular cohort of learners. Given the authors’ professional and academic interests in space and spatial relationships as a unifying theme in geography, the *Hashiwokakero* puzzle was reimagined for that purpose. The design of the puzzle was not explicitly geography-focused to provoke participants to be aware of (what might first appear to be) peripheral elements of the virtual environment, such as the color-coded safe-distancing indicators. The latter were deliberately not brought to the attention of participants during the briefing before the embodied game play. This design potentially allowed more metacognitive participants to wonder about the true objective of the SORBET activity, thereby leading to more insightful post-activity reflection.

Responses in Terms of the Importance of Community

Virtual environments can be challenging within which to orientate oneself. This is a struggle that most students will also be expected to face, as there are learning curves to anything new, especially technology (Yannie, 2000). Notably, participant A shared how she

tapped the frustration to her eventual advantage. Despite the difficulties, she felt motivated to master the user interface and was eventually able to do so with the help of her partner.

Participant A: The actions of building the roads were initially slightly difficult to learn. The stretching of the blocks to create the bridges was slightly difficult for me because the function was not automatically enabled when we entered the virtual realm. However, with the aid of Participant F who sat beside me during the activity to show me how to operate the controls and enabling the stretching function, building the roads were made significantly easier and there were no troubles from then. The initial difficulty to build the roads did not impede my enjoyment of the learning experience, rather it fueled a sense of motivation to be able to control the avatar proficiently. The difficulty was not too great and was overcome rather quickly. As such, it did not impede my learning since the difficulty was not too great. However, I do foresee that if I could not learn how to build the roads after a long while and trying multiple times, it may impede my sense of enjoyment.

Participant A’s response highlights the importance of a companion (or a community, by extrapolating to the cultural-historical activity theory) in improving the learning experience. This improvement can be achieved in the form of simply helping her navigate the virtual world, or in terms of the general teamwork required among participants to build bridges and solve the puzzle. Thus, the CHAT framework is foregrounded once again as an important foundation to the SORBET activity.

LIMITATIONS

The study reported in this article was carried out as an independent research project by the second author, under the auspices of what is known as the Undergraduate Research Experience on Campus (URECA) program of the Nanyang Technological University, Singapore. Projects under this program do not benefit from being funded by research grants, and are scoped to be carried out to complete within an academic year. As such, the design and enactment of the project was subject to a number of constraints, even before taking in to account safe distancing protocols obligated by the COVID-19 pandemic. These constraints have resulted in the following limitations.

As already described, this study only reports responses from participant interviews carried out after the activity. Timetabling constraints did not permit more in-depth triangulative measures to establish trustworthiness, such as talking through the emergent and eventual layout of the bridges with the participants during the co-construction process. Participants were also selected on the basis of convenience sampling, leveraging the second author’s social network of fellow teachers-in-training.

Another limitation arose from the high ratio of available (virtual) land area to the number of participants: at the scale of the avatar, this ratio was an area 256 m by 256 m square, for the nine participants to participate in the embodied half of the activity. This high ratio would have contributed to the low infection rate, since, geographically speaking, the population density within the (virtual) environment was not high.

In terms of the SORBET activity, the approach was largely predicated on the immersion that a learner could experience within the virtual world. Deep immersion stems from a strong sense of authenticity—that the learner feels that the elements of the virtual environment, including the scenario taking place in the virtual world, is real. Hence, one could argue that learning through the SORBET approach could be limited if students were uninterested in the virtual world. However, education research has reflected that effective use of technology has indeed increased student motivations in learning (Kearsley and Shneiderman, 1998; Heafner, 2004; Granito and Chernobilsky, 2012). More recent studies in geographical education (Turan et al., 2018; Šašinka et al., 2019; Syvyi et al., 2022) also reinforce the notion that technology increases student motivation and augments their learning experience. The teacher can also act as the intermediary, using their rapport with students to encourage them to explore new platforms for learning and minimize (or nullify) this limitation.

CONCLUDING REMARKS

This article has described a study which is part of a larger body of work using a curricular approach known as the Socially Responsible Behavior through Embodied Thinking (SORBET) Project to help enculturate in learners' dispositions and behaviors compatible with protocols obligated by the COVID-19 pandemic.

The study has suggested that the use of the cultural–historical activity theory (CHAT) is a suitable lens through which to analyze the interactions among the various elements of the SORBET approach which facilitate the meeting of its objective. Specifically, this study has given an example of a design in which the object (of CHAT) is curricular, while the outcome is value-oriented.

To elaborate, in Singapore, the geography curriculum in state-funded schools aims to convey authentic disciplinary messages to learners to help them make sense of the spaces they interact with directly. Among the aims of the syllabus is for students to “understand the interactions between places and the patterns of networks created by movements between these places” (Ministry of Education, 2021, p. 5).

This study has also suggested that—should the curricular focus of the SORBET approach be geographical—one possible context of enactment which would be authentic to learners might be in the form of a *Hashiwokakero* activity, in which learners need to negotiate with and collaborate alongside each other as they co-construct networks within a spatially delimited area, all while a (virtual) virus is being diffused among the members of the community.

The authors see this latter point as of potential value to the wider geographical fraternity because *Hashiwokakero* has traditionally been construed as a mathematical (and not a geographical) puzzle, and, further, one which has been played on an individual (as opposed to a communal) basis. Additionally, this study has suggested the viability of conducting a *Hashiwokakero* activity in a three-dimensional virtual space, as opposed to its original roots in pen and paper.

While not reported in this study, the most recent iterations of the SORBET approach have been carried out as a bespoke ground-up app developed using the Unity game engine, after

the benefit of a year's enactment in various contexts and reflections thereupon. This re-written codebase attempts to address many of the areas of relative weakness of the earlier iterations (including the iteration reported in this study), such as a relatively opaque user interface and a low aggressiveness of infection.

In the long term, SORBET seeks to nurture the disposition of learners taking responsibility for their actions in the social context of a pandemic. Dispositional change takes time (Warburton, 2003; Smith and Colby, 2007), and this study has applied the cultural–historical activity theory to make some of the catalytic conduits of such dispositional change less tacit. In turn, the yet naïve and emerging understandings of learners to appropriate norms of behavior can thus subsequently be dialogued upon among peers, as facilitated by the teacher. As students navigate the tensions between—on the one hand—maintaining safe distance, and—on the other—engaging in collaborative behaviors for the good of the wider community, it might just be possible for the growing awareness of spatiality of the pandemic to translate to a deepened geographical perspective at both local and global scales. By affording learners with an individual agency and a geographic epistemology through which they might interface with the pandemic, learning in SORBET is active and embodied.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Nanyang Technological University Institutional Review Board. The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the minor(s)' legal guardian/next of kin for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

KL was responsible for the concept and design and provision of the SORBET environment to S. KL suggested the theoretical framework to SL. SL enacted the intervention and was responsible for participant recruitment and data analysis. Both authors were responsible for the writing of the Discussion.

ACKNOWLEDGMENTS

We wish to acknowledge the funding support for this project from Nanyang Technological University under the URECA Undergraduate Research Programme.

REFERENCES

- Andersson, D. (2009). *Hashiwokakero* Is NP-Complete. *Inf. Process. Lett.* 109 (19), 1145–1146. doi:10.1016/j.ipl.2009.07.017
- Barsalou, L. W. (2010). Grounded Cognition: Past, Present, and Future. *Top. Cogn. Sci.* 2 (4), 716–724. doi:10.1111/j.1756-8765.2010.01115.x
- Batty, M. (1997). Virtual Geography. *Futures* 29 (4–5), 337–352. doi:10.1016/s0016-3287(97)00018-9
- Clark, A. (2017). Embodied, Situated, and Distributed Cognition. *A companion Cogn. Sci.*, 506–517. doi:10.1002/9781405164535.ch39
- Coelho, L. C., Laporte, G., Lindbeck, A., and Vidal, T. (2019). *Benchmark Instances and Branch-and-Cut Algorithm for the Hashiwokakero Puzzle*. arXiv preprint arXiv:1905.00973.
- Cresswell, T. (2013). *Geographic Thought: A Critical Introduction*, 8. John Wiley & Sons.
- Engeström, Y. (2014). *Learning by Expanding: An Activity-Theoretical Approach to Developmental Research*. Helsinki: Orienta-Konsultit Oy.
- Gee, J. P. (2003). *What Video Games Have to Teach Us about Learning and Literacy*. New York, NY: Palgrave Macmillan.
- Gibson, J. (1979). *The Ecological Approach to Visual Perception*. Boston, MA: Houghton, Mifflin and Company.
- Gordon, E. (2008). The Geography of Virtual Worlds. *Space Cult.* 11 (3), 200–203. doi:10.1177/1206331208319742
- Granito, M., and Chernobilsky, E. (2012). *The Effect of Technology on a Student's Motivation and Knowledge Retention*.
- Gregory, D., Johnston, R., Pratt, G., Watts, M., and Whatmore, S. (2011). *The Dictionary of Human Geography*. John Wiley & Sons.
- Heafner, T. (2004). Using Technology to Motivate Students to Learn Social Studies. *Contemp. Issues Technol. Teach. Educ.* 4 (1), 42
- Kearsley, G., and Shneiderman, B. (1998). Engagement Theory: A Framework for Technology-Based Teaching and Learning. *Educ. Technol.* 38 (5), 20
- Lambert, D. (2017). "Thinking Geographically," in *The Handbook of Secondary Geography*. Editor M. Biddulph (London, UK: The Geographical Association), 20–29.
- Lefebvre, H., and Nicholson-Smith, D. (1991). *The Production of Space*, 142. London, England: Oxford Blackwell.
- Leont'ev, A. N. (1981). *Problems of the Development of Mind*. Moscow: Progress Publishers.
- Lim, K. Y. T. (2015). *Disciplinary Intuitions and the Design of Learning Environments*. Dordrecht, Netherlands: Springer.
- Lim, K. Y. T., Yuen, M.-D., Hilmy, A. H., Chua, S. Y., Lee, J. S. W., and Ng, J. J. L. (2022). "The Use of Immersive Environments for Learning in Singapore Schools, 2009 – 2019: Lessons from a Decade of Scaling and Translation of the Disciplinary Intuitions/Six Learnings Programme," in *Scaling up ICT-Based Innovations in Schools - the Singapore Experience*. Editors E. R. Koh and D. Hung (Dordrecht, Netherlands: Springer).
- Lim, K. Y. T., Yuen, M.-D., Leong, S. L., Hilmy, A. H., Lim, L. J. T., and Ng, J. J. L., (2020). The Socially Responsible Behaviour through Embodied Thinking (SORBET) Project: the Design of an Immersive Environment Which Models the Diffusion of Virus Infection to Help Students of Mathematics Learn Probabilities. In Proceedings of the 6th international conference of the Immersive Learning Research Network, 255–258.
- Lincoln, Y. S., and Guba, E. G. (1989). *Naturalistic Inquiry*. Newbury Park, CA: Sage Productions Inc.
- Louise Barriball, K., and While, A. (1994). Collecting Data Using a Semi-structured Interview: a Discussion Paper. *J. Adv. Nurs.* 19, 328–335. doi:10.1111/j.1365-2648.1994.tb01088.x
- Mahon, B. Z. (2015). What Is Embodied about Cognition *Lang. Cogn. Neurosci.* 30 (4), 420–429. doi:10.1080/23273798.2014.987791
- Mansilla, V. B., and Gardner, H. (2009). "Disciplining the Mind," in *Challenging the Whole Child: Reflections on Best Practices in Learning, Teaching, and Leadership*. Editor M. Scherer (Alexandria, VA: ASCD), 97–107.
- Ministry of Education (2021). *Geography Syllabus Upper Secondary*. Retrieved From: https://www.seab.gov.sg/docs/default-source/national-examinations/syllabus/olevel/2022syllabus/2236_y22_sy.pdf (Accessed on July 3, 2021).
- OpenSimulator (2020). What Is OpenSimulator Retrieved From: http://opensimulator.org/wiki/Main_Page (Accessed on July 3, 2021).
- Preissle, J., and Le Compte, M. D. (1984). *Ethnography and Qualitative Design in Educational Research*. Academic Press.
- Ratey, J. J. (2001). *A User's Guide to the Brain: Perception, Attention, and the Four Theatres of the Brain: Vintage*.
- Roth, W.-M., and Lee, Y.-J. (2007). "Vygotsky's Neglected Legacy": Cultural-Historical Activity Theory. *Rev. Educ. Res.* 77 (2), 186–232. doi:10.3102/0034654306298273
- Roth, W.-M., Radford, L., and LaCroix, L. (2012). Working with Cultural-Historical Activity Theory. *Forum Qual. Sozialforschung/Forum Qual. Soc. Res.* 13 (2).
- Sanchez-Vives, M. V., and Slater, M. (2005). From Presence to Consciousness through Virtual Reality. *Nat. Rev. Neurosci.* 6 (4), 332–339. doi:10.1038/nrn1651
- Šašinka, Č., Stachoň, Z., Sedlák, M., Chmelík, J., Herman, L., Kubíček, P., et al. (2019). Collaborative Immersive Virtual Environments for Education in Geography. *ISPRS Int. J. Geo-Information* 8 (1), 3.
- Shapiro, L. (2019). *Embodied Cognition*. New York, NY: Routledge.
- Smith, T. W., and Colby, S. A. (2007). Teaching for Deep Learning. *The Clearing House: A J. Educ. Strateg. Issues Ideas* 80 (5), 205–210. doi:10.3200/tchs.80.5.205-210
- Soja, E. W. (1989). *Postmodern Geographies: The Reassertion of Space in Critical Social Theory*. London, England: Verso.
- Steuer, J. (1992). Defining Virtual Reality: Dimensions Determining Telepresence. *J. Commun.* 42 (4), 73–93. doi:10.1111/j.1460-2466.1992.tb00812.x
- Syvyi, M., Mazbayev, O., Varakuta, O., Panteleva, N., and Bondarenko, O. (2022). *Distance Learning as Innovation Technology of School Geographical Education*. arXiv preprint arXiv:2202.08697.
- Thrift, N. (2003). Space: the Fundamental Stuff of Geography. *Key concepts Geogr.* 2, 95–107.
- Turan, Z., Meral, E., and Sahin, I. F. (2018). The Impact of mobile Augmented Reality in Geography Education: Achievements, Cognitive Loads and Views of university Students. *J. Geogr. Higher Edu.* 42 (3), 427–441. doi:10.1080/03098265.2018.1455174
- Vygotsky, L. S. (1978). *Mind in Society: The Development of Higher Psychological Processes*. Cambridge, MA: Harvard University Press.
- Warburton, K. (2003). Deep Learning and Education for Sustainability. *Int. J. Sus Higher Ed.* 4 (1), 44–56. doi:10.1108/14676370310455332
- Yannie, M. (2000). Technology Is Us: Do We Have Time to Learn? *Techtrends Tech. Trends* 44 (4), 42–43. doi:10.1007/bf02818192

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The handling editor declared a past co-authorship with one of the authors KL.

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