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Designing For The Nurturing of New Norms of Social Responsibility With The Socially Responsible Behaviour Through Embodied Thinking (SORBET) Project

Kenneth Y T Lim[1] [0000-0003-3756-6625], Jie Bin Lok[1] and Ming De Yuen[1]

[1] National Institute of Education, Singapore
kenneth.lim@nie.edu.sg

Abstract. This paper describes the translation of a pedagogical approach origi-nally developed in response to the changing contexts of learning as a result of the COVID-19 pandemic. The Socially Responsible Behaviour through Embodied Thinking (SORBET) project aimed to develop a virtual learning environment that could be used across various disciplinary domains to nurture socially responsible behaviour through embodied cognition. The authorial team successfully devel-oped and trialled the SORBET pedagogy using an open-source immersive envi-ronment which was scalable and had low network infrastructure requirements. The study reported in this paper sought to ensure currency and relevance of the SORBET approach in an evolving social context in 2021 – 2023, cognizant of a nationwide vaccination programme in Singapore that took place in the latter half of 2021. This project expanded the SORBET platform by developing a new mo-bile-compatible version. The result was a tool that teachers were able to imple-ment and adapt across different grade levels and disciplinary concepts. This per-mitted opportunities for teachers to connect student learning to real-world sce-narios. The qualitative feedback from students highlighted the engaging nature of the SORBET environment and its potential to support collaborative learning and problem-solving skills.

Keywords: Embodied Cognition, Epistemic Games, Game-Based Learning, Mobile Learning, Citizenship Education, COVID-19.

1 Introduction

The Socially Responsible Behaviour through Embodied Thinking (SORBET) project was conceptualized in response to the evolving educational landscape in Singapore, particularly in light of the COVID-19 pandemic and the increasing emphasis on digital learning. The project aimed to develop a virtual learning environment that could be used across various disciplinary domains to nurture socially responsible behaviour and enhance students' understanding of complex concepts through embodied cognition.

The project has its origins in lesson units designed by Mathematics teachers of a Networked Learning Community in Singapore, whose members approached the authorial team to take their face-to-face pedagogy and transpose it to a remote learning / home-based learning / blended learning context in late March 2020. The authorial team successfully developed and trialed the SORBET pedagogy using an open-source immersive environment which was scalable and had low network infrastructure requirements. The approach was also flexible because it could be carried out in face-to-face settings and / or remote settings. The original team of Mathematics teachers was satisfied with the successful translation of their face-to-face pedagogy to a blended learning setting, and conducted lessons in 2020. However, this immersive environment was only compatible with Windows and MacOS platforms.

The study reported in this paper sought to ensure currency and relevance of the SORBET approach in an evolving social context in 2021 – 2023, cognizant of a nation-wide vaccination programme in Singapore that took place in the latter half of 2021. By doing so, the built on prior work with the Six Learnings curricular framework [1] and afforded teachers with deeper understanding of how well-designed immersive environments – accessed through a variety of personal learning devices – may be used to effect dispositional change among learners. This project expanded the SORBET platform by developing a new mobile-compatible version. This mobile-first

approach aligned with the Singapore Ministry of Education's accelerated roll-out of personal learning devices to all secondary school students.

By ensuring compatibility with iOS, Android, Windows, and Mac devices, the new SORBET platform aimed to integrate into various learning contexts, including face-to-face classroom settings, remote learning scenarios, and blended learning approaches.

From the perspective of school-going children during the onset of the COVID-19 pandemic, they experienced changes to their daily routine at home and at school. These experiences would have brought home the realities of life changed under COVID-19, even if they may not have yet fully comprehended the nature of what viruses are and the ways in which they may spread through communities. For instance, at the onset of the pandemic, there were several anecdotal reports of adolescents and older students not taking recommended protocols of safe distancing sufficiently seriously (for example, [2] and [3]). Early attempts to convey the gravity of practising good social responsibility included the use of print media [4] and web-based media (eg, [5]).

In the context of day-to-day interactions with others in a time of COVID-19, the fundamental problematic which the SORBET environment sought to address was the disconnect between everyday interaction (and the decision-making processes underlying it) with feedback on our action and decisions (with respect to the practice of social responsibility) which would only come the following day through the publication of case numbers. This feedback suffered from (a) a time lag, and (b) a lack of context - the feedback was general to the population as a whole and not particular to the decisions and actions of any given individual / learner. From this framing, the SORBET project addressed several key challenges in the current educational landscape: limited mobile-compatible resources for teaching probabilistic concepts in an embodied manner; need for effective blended learning solutions adaptable to various contexts; long-term relevance of health behaviour education tools; and alignment with national educational policies on digital literacy and 21st-century competencies.

The development of SORBET aimed to provide a versatile platform that could sup-port these educational needs while aligning with current policy goals. The SORBET environment comprised two complementary halves, both or either or which may be conducted in face-to-face / remote-learning / home-based learning / blended learning contexts (or, any combination thereof). The approach addressed the preceding concerns through its use of an open-source immersive environment which could be enacted in a variety of remote- and / or face-to-face contexts.

The first way the SORBET approach addressed the preceding concerns was because learners - through their avatars - were given visual augments of safe radii, colour-coded depending on proximity to others.

The second way the SORBET approach addressed the preceding concerns was be-cause the teacher and the learners had the opportunity to access and examine the (simulated) ‘infection data’ through a web-based dashboard, designed in accordance with worksheets put together by Mathematics teachers in a Networked Learning Community at the Academy of Singapore Teachers.

Over the long run, SORBET sought to nurture the disposition of learners taking responsibility for their actions, in the social context of a pandemic. Human agency there-fore lay at the heart of the SORBET Project.

In terms of ethical considerations, SORBET afforded learners the opportunity to interact with social others (their peers) in a virtual environment in which learners safely explored for themselves the consequences of the decisions they took regarding the practice of mask-wearing, vaccinations, hand-washing and other socially responsible behaviours (since the environment of interaction was virtual and therefore free of Real World viruses).

While scenarios of learning to help students of all ages (and the general populace) better understand the probabilistic nature of the diffusion of viruses can be - and have been (for example, [5]) - designed, they have largely been web-based, or - more generally - designed from the paradigm of a virtual laboratory setting.

In contrast, with its emphasis on learner agency and ownership of their behaviours, learning in SORBET is active and embodied. As argued by [6], there is empirical evidence that the human mind tries to replicate and mimic grounded experiences with concrete outcomes, from knowledge gains to emotions.

2 Methods

The project employed an iterative development approach across three cycles, implemented at three sites in Singapore. The project was conducted from November 2021 to May 2024, in accordance with the prevailing IRB protocols IRB-2021-477 of the Nanyang Technological University, Singapore, through which informed consent of the participants was sought and obtained.

2.1 Participant Profile

The SORBET project involved a total of 200 student participants from three educational sites in Singapore, representing both primary and secondary school levels. Additionally, four teachers participated in implementing

the SORBET lessons across these sites. Site 1 was a secondary school from which 100 students aged 13 to 14 were recruited from five classes. At site 2, 20 students aged 13 to 14 participated. Site 3 was a primary school from which 80 students aged 10 to 11 were recruited from four classes. This latter site demonstrated the adaptability of the SORBET approach to younger learners and consequently its potential for longitudinal implementation.

The diverse sample of students across different educational levels and years provided comprehensive feedback on the design the SORBET application and its adaptability in various learning contexts.

2.2 Development Timeline

The project followed an iterative development cycle, with each phase building upon the insights and feedback from the preceding one.

The first phase took place from November 2021 till September 2022. During this phase, ethics clearance from the university was obtained, as was data collection approval from the Singapore Ministry of Education. Meetings with stakeholders from schools were initiated, during which the first round of lesson units was co-designed in close collaboration with teachers.

These lesson units were integrated into disciplinary domains such as Mathematics and Social Studies, and were conducted during regular scheduled curriculum time. A first iteration of the mobile-compatible SORBET application was developed and feedback was sought from stakeholders.

The second phase took place from October 2022 till July 2023. It was during this cycle that Singapore lifted restrictions related to the COVID-19 pandemic. Teachers from sites 1 and 3 conducted their lesson units and the authorial team conducted focus group discussions with students. This helped the iterative improvement of the SORBET app. It was also during this phase that lesson units were refined in time for the third cycle.

The third phase took place from August 2023 till May 2024. Teachers from sites 2 and 3 conducted their lesson units and the authorial team conducted focus group discussions with students. The lesson units were further refined and compiled in to lesson packages, which – together with accompanying documentation – were subsequently made available to the Ministry of Education in accordance with protocols related to the funding of the project.

2.3 Data Collection and Analyses

As outlined in the preceding section, the development approach of the SORBET project was consistent with the principles of Design Based Research. Data was obtained qualitatively through the conduct of classroom observations, focus group discussions and the examination of lesson plans authored by the teachers.

During classroom observations, the authorial team made field notes on student engagement, interactions and on any technical issues encountered. After each lesson implementation, a focus group discussion was conducted with students on a voluntary basis, in order to better understand their perspectives. These discussions were audio-recorded and were conducted in accordance with the principles of informed consent and the anonymisation of data, consistent with the prevailing policies of the university with which the authorial team is affiliated. Finally, lesson plans designed by the teachers themselves were catalogued in order to better understand how the SORBET approach might be integrated within different disciplinary domains.

Analyses of data from these measures focused on informing improvements to the SORBET application and the curricular units, ensuring that the development process was guided by real-world classroom experiences and feedback from students.

3 Results

This section focuses on how teachers implemented their lessons and adapted them to their specific contexts. The reporting of data incorporates verbatim feedback from students to illustrate the impact of the development process. In preliminary work [7], the authorial team found that students generally responded positively to the SORBET approach. On a five-point Likert scale, students reported finding the activity interesting (mean score 3.55 out of 5) and expressed interest in playing more of the activity in school (mean score 3.43 out of 5). However, they also reported facing some difficulties in participation (mean score 3.68 out of 5).

In a follow-up study using pre- and post-intervention surveys in 2021, we found statistically significant improvements in several key areas related to social responsibility and civic consciousness. For the survey items: students' belief that they could make a difference in Singapore's response to the COVID-19 pandemic increased significantly ($p < 0.001$); students reported thinking more about how their actions could affect others ($p = 0.0196$); students showed increased care about how their actions could affect others ($p = 0.01433$); students' belief in their

ability to contribute to the community as young people increased ($p = 0.01822$); and students' feelings that they could make a positive difference to their country improved ($p = 0.02182$).

These preliminary findings suggested the potential of the SORBET approach to nurture socially responsible dispositions and informed the subsequent development and implementation of the project.

3.1 Common Elements across all Sites

The SORBET project resulted in the successful development and implementation of the SORBET application and associated lesson packages across three diverse sites in Singapore.

Across all three sites, the SORBET implementation included a trash collection activity as an in-game task for students to complete. While this was not the primary focus of the lessons at Sites 1 and 2, it served as an engaging element that encouraged exploration of the virtual environment and provided a tangible goal for students.

The collaborative nature of the SORBET environment was evident across all sites. One student noted, "Basically, it's like, it requires a lot of teamwork, and you have to know the person that you are working with." This teamwork extended to strategic thinking, as another student explained their approach: "So basically the map, we split it in half. I do one half and together my two teammates do the other half, like that."

3.2 Secondary School Models of Probability and Diffusion

Teachers implemented SORBET in Secondary Two mathematics lessons, with a primary focus on probability concepts, specifically dice roll distribution.

Teachers guided students through a process of collecting data on the numbers of 'infected' classmates over several cycles. Students recorded this data in tables, noting the number of newly infected people and the total number of infected people for each cycle. This hands-on data collection helped make abstract probability concepts more tangible. They then extended this to discussions about more complex models of diffusion.

Typically, a lesson plan would include: an introduction to probability concepts; the SORBET simulation activity, including trash collection; data collection and analysis from SORBET, focusing on dice roll outcomes; probability calculations and analysis (including graph plotting activity); an introduction to the Susceptible, Infected, Recovered (SIR) model; a comparison of SORBET simulation with SIR model; and discussion of real-world applications and limitations of models.

The graph plotting activity enabled students to visualize the spread of infections based on their calculations. It is important to note that while SORBET itself did not model the SIR components, teachers used it as a starting point to discuss more complex disease models. This approach allowed teachers to illustrate the process of refining models to better represent real-world scenarios, deepening students' understanding of both the usefulness and limitations of mathematical models in studying disease spread. The iterative improvements in the SORBET application were evident at this site, with students noting enhanced user interface and cross-device compatibility. However, some technical challenges remained, as one student pointed out, "the camera was really difficult to control." This feedback was valuable for further refinement of the application.

3.3 Primary School Spatial Awareness and Geometry

Teachers adapted SORBET for use with younger students, implementing it over two phases.

First, teachers structured lessons around map reading and navigation skills. The collaborative nature of the tasks was evident in student feedback. One student described their team's strategy: "We decided that one person will stay at the entrance which is the centre. The rest of us will split up and when it's time for us to call the person to help, we will tell them where we go and where we have covered."

The immersive nature of the environment presented both opportunities and challenges. A student commented on the scale of the virtual world: "I feel like the map is a bit too big because I was picking trash at one corner. I was like, yes, finally I picked one trash. Then I look at my map, like, oh, map on the other corner. I'm running again." This feedback helped teachers adjust the scope of activities in subsequent lessons.

In the second implementation, teachers shifted focus to geometry concepts. Students explored 2D shapes and 3D objects in the virtual world, enhancing their spatial aware-ness and geometric understanding. The design of the virtual environment supported these learning objectives, as noted by a student: "One thing that did pretty well is that, every building, like every part, for example the map, a certain area of houses, it doesn't appear more than twice. So you can find it all the way around the map."

Students also demonstrated the development of navigation and problem-solving skills. One student explained their strategy: "First, I try to find my location first. And using the circle that shows the part of the map, I know where I am and using the paper map, I know which direction I need to go." Another student noted, "However, if I go the right way, I can easily find the quickest way to go to where is the trash."

3.4 Teacher Adaptations and Iterative Improvements

Throughout the implementation process, teachers adapted the SORBET lessons to fit their specific classroom contexts. Technical challenges noted in earlier implementations, such as navigation difficulties, informed iterative improvements to the SORBET application. These improvements were incorporated into subsequent versions of the app, demonstrating the project's responsiveness to teacher and student feedback.

In summary, the SORBET project produced a versatile tool that teachers were able to implement and adapt across different grade levels and disciplinary concepts. While the primary focus remained on core curricular objectives such as probability and geometry, the application's flexibility allowed for connections to interdisciplinary topics and real-world scenarios. The qualitative feedback from students highlighted the engaging nature of the SORBET environment and its potential to support collaborative learning and problem-solving skills. The mobile compatibility of the application allowed for easy integration into regular classroom settings, while the iterative development process enabled continuous improvement based on classroom experiences.

4 Discussion

The SORBET project has contributed to our understanding of game-based learning and immersive learning environments in teaching and learning, with implications for theory, practice, and policy. These contributions are directly informed by the project findings and the lessons conceptualised, designed and enacted by teachers.

The successful implementation of probability and geometry concepts through SORBET demonstrates the potential for integrating game-based learning into teacher education curricula. For example, the lesson units from Site 1, which focused on prob-ability and data analysis, provides a concrete model for teaching abstract mathematical concepts through interactive, immersive environments. Further, the lesson units demonstrated the affordance of the SORBET approach to bridging the abstract with the concrete, as participants connected probability theory with models relating to the diffusion of viruses in communities. As a result, the iterative development process and its responsiveness to teacher and student feedback offer a template for courses in the learning sciences on designing and refining epistemic games.

In terms of teacher professional learning, the project suggests how teachers can adapt game-based learning to different contexts. For instance, the transition from using SORBET for probability concepts in secondary schools to spatial awareness in primary schools demonstrates its versatility and applicability to differentiated instruction, in-forming professional development on technology integration across subjects and grade levels. Additionally, the feedback from students, such as comments on the engaging nature of the lessons and the development of problem-solving skills, provides evidence for the effectiveness of this approach. In this vein, the three lesson packages developed by teachers from primary and secondary schools (namely, on probability and data analysis, disease diffusion models, and on spatial awareness / geometry) offer scaffolds for creating game-based learning resources across various disciplinary domains and cater-ing to the needs of learners from a range of age cohorts. Feedback on student engagement and collaborative learning, as evidenced by student quotations such as "it requires a lot of teamwork," suggest that these materials can promote active, cooperative learning environments. In terms of implications to broader education policy, the successful implementation of SORBET across face-to-face, remote, and blended learning contexts aligns with goals common to many education systems for flexible implementation models. The mobile compatibility of the application, allowing students to use their personal learning devices in regular classrooms, demonstrates its potential in supporting diverse learning environments. The success of the SORBET project in the teaching and learning of complex mathematical concepts such as probability theory through embodied learning sup-ports policies promoting innovative approaches to STEM education. The collaborative nature of the learning activities within the SORBET environment – within which one navigated communal spaces within which a (virtual) virus was being diffused – helped nurture pro-social values and behaviours associated with 21st century competencies such as teamwork and problem-solving.

The project has also revealed several elements of game-based and immersive learning that are potentially translatable and scalable. These include cross-platform accessibility, flexible lesson design, and the informing of teacher professional learning and the design of models for professional development. For example, the development of SORBET for iOS and Android handhelds, as well as Windows and Mac computers is demonstrated by its successful use on personal learning devices in regular classrooms in its contexts of use. The adaptation of SORBET from lessons in probability theory at the secondary school grade levels to introductory lessons in coordinate geometry at the primary school grade levels showcases how well-designed game-based learning curricula can be translated across disciplinary domains and grade levels. Finally, the iterative

improvement process, incorporating feedback from teachers and students, provides a model for ongoing professional development in the integration of educational technology in to everyday curricula.

These outcomes, supported by both quantitative improvements in student attitudes and qualitative feedback on engagement and learning, suggest that game-based learning and immersive learning environments have significant potential for wider implementation across Singapore's education system. The SORBET project offers scalable solutions to enhance teaching and learning across various subjects and competencies, aligning closely with national educational goals and policies aimed at preparing students for the future.

5 Concluding Remarks

UNESCO [8] has estimated in April 2020 that 138 countries had closed their schools to a national capacity, resulting in the educational disruption to approximately 80% of children worldwide [9]. Considering this unprecedented COVID-19 global outbreak, the sustainability of effective learning has been identified as a significant challenge across all levels of education ([10], [11], and [12]). This causes significant disruptions to students' learning and assessments.

In guidance given to schools by the Singapore Ministry of Education [13], teachers and school leaders are given autonomy to - among other things - determine the nature of learning activities on Home-Based Learning (HBL) Days and to plan the scheduling of the subject coverage, under the MOE's Flexible Parameters for Designing HBL Days.

In 2020, Full Home-Based Learning was implemented across all schools from 8 April 2020, a day after Singapore entered the circuit breaker [14]. It lasted for about a month until 4 May before the school holidays began. In June that year, students from different levels alternated between HBL and classes in school weekly. During the month of Full HBL, they spent about four to six hours a day on both online and offline learning. About a year later, on May 8th, 2021, Singapore entered Heightened Alert status and all schools – primary, secondary, and junior colleges - switched again to Full Home-Based Learning on May 16th, 2021. Primary One, Two, and Three students continued with Full Home-Based Learning till July 6th, 2021. All primary schools implemented Full Home-Based Learning again from September 27th till October 7th, 2021. Eventually, all COVID-19 protocols were lifted nationally in April 2023.

In this paper, we have described the development and implementation of an intervention in response to the needs of learners during the pandemic, and have also de-scribed how teachers adapted the approach to a post-COVID-19 milieu. The SORBET project has demonstrated significant potential in nurturing socially responsible dispositions through its infusion in to disciplinary domains as diverse as mathematics and social studies.

We acknowledge the following limitations of the study. In terms of sample size and diversity, the project was implemented in only three schools (two secondary and one primary) in Singapore. While this provided valuable insights, it may not fully represent the diverse range of school contexts and student populations across the country. A larger and more diverse sample would be needed to generalize the findings more broadly. Second, in terms of duration of implementation, the project was conducted over a necessarily limited timeframe due to constraints of funding, with sites experiencing only one or two phases of implementation. Long-term effects and the sustainability of engagement with SORBET over extended periods remain to be studied. Third, in terms of technical challenges, the first round of implementations (in phase two) faced some technical issues, particularly with user interface and controls. While these were largely addressed by the third and final phase, they may have influenced early user experiences and data collection.

These limitations provide opportunities for future research and development of the such game-based learning approaches. Addressing these aspects in subsequent studies would further strengthen the evidence base for SORBET's effectiveness and applicability in diverse educational contexts.

The SORBET project has successfully developed a mobile-compatible game-based learning platform and associated lesson packages for use in Singapore schools. Through its implementation across primary and secondary schools, the project has demonstrated the potential of these approaches to engage students and bridge abstract concepts with real-world applications.

Future work could explore: gradual scaling of game-based and immersive learning implementations across more schools in Singapore, with continued monitoring and evaluation of their impact; development of additional subject-specific modules to expand the application of these approaches beyond mathematics, leveraging the versatility demonstrated in the current implementations; integration of game-based and immersive learning principles into pre-service and in-service teacher training programs to support wider adoption, building on the successful co-design process with teachers in this project; further research into the long-term effects of these approaches on student engagement and learning across various subjects, expanding on the preliminary findings

of this study; and continued refinement of game-based and immersive learning applications based on user feedback, with a focus on enhancing user experience and expanding learning scenarios.

In conclusion, the SORBET project has made significant strides in demonstrating how game-based learning and immersive learning environments can be developed and integrated into Singapore's education system. The project's success in engaging students across different grade levels and subjects, its adaptability to various learning contexts, and its alignment with national educational goals provide a strong foundation for future development of innovative, technology-enhanced learning tools. While further research is needed to fully understand its long-term impact, SORBET offers a promising approach to preparing students for the challenges of the 21st century through interactive, immersive learning experiences.

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