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Optimizing Virtual Learning for Classical Poetry: Insights From Spatial Analytics of Student Engagement

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Abstract. Immersive virtual learning environments (VLEs) hold transformative potential for humanities education, particularly in subjects like classical poetry, which can be abstract for novice learners. To understand student engagement and optimize VLE design for fostering interest in Haiku, a traditional Japanese poetry form, it's crucial to move beyond traditional assessment methods. This study explores spatial behavior analysis as a means to evaluate student interaction within a custom VLE centered on a Japanese Haiku master's historical journey. We developed two types of VLEs featuring either locations tied to a recreation of the poet's journey embedded in a geographic 3D model. By tracking the position and orientation data of 208 informatics students as they navigated these spaces, we sought to determine if these metrics correlate with levels of engagement and how best to optimize VLEs for enhanced student interest. K-means clustering segmented students by interaction time with key elements, uncovering diverse exploration patterns. These ranged from targeted assignment completion to extensive engagement with supplemental content. Specific clusters also suggest areas where enhanced instructions may be needed. These findings empirically demonstrate how this approach enables educators to iteratively tailor VLE designs to individual learner needs and create engaging, immersive experiences that support the complex study of classical poetry. This study provides a model for leveraging spatial analytics to guide development and refinement of innovative learning experiences in virtual spaces.

Keywords: Virtual Reality, Mozilla Hubs, Virtual Spaces, Learning Analytics.

1 Introduction

The rapid advancement of virtual technology is ushering in a new era of innovative educational opportunities. Virtual learning environments (VLEs) offer unparalleled accessibility beyond physical classrooms, allowing students to explore diverse educational landscapes without temporal or spatial constraints. Particularly in the realm of humanities, the capabilities of VLEs offer transformative advantages over traditional pedagogical methods. Existing teaching practices of the subjects like Haiku, a form of traditional Japanese poetry, often fail to adequately convey the layers of subtle meaning, leading to a superficial understanding of the art form [10]. Furthermore, the abstract nature of Haiku can make it difficult for students to engage with and relate to the subject matter [13]. However, immersive environments have the potential to contextualize the creation of Haiku within its historical and natural landscapes, mostly in rural areas, and allow students in classrooms to interact with these elements in a multi-sensory way.

While immersive VLEs offer promising opportunities for revitalizing humanities subjects, they also complicate traditional methods of educational assessment. Common metrics, such as exams and in-person observations, are less applicable in these digital landscapes, especially when dealing with nuanced subjects. This necessitates new, adaptive evaluation methods that can accurately assess student behavior and engagement within these complex virtual settings. One potential solution is the analysis of spatial behaviors, an approach already used in the gaming industry [12]. In a previous study, we introduced a system that tracks and visualizes students' positions and gaze directions within Mozilla Hubs. This system offers real-time tracking of student movements and attention, providing valuable insights into their levels of engagement and focus [15]. This method presents a robust alternative to traditional assessment, capturing real-time and nuanced data that were previously difficult to obtain.

To bridge the gap between the potential of immersive virtual learning environments (VLEs) for humanities and the need for new assessment methods, this study explores spatial behavior analysis to evaluate student engagement in Haiku learning. By analyzing head position and orientation data in a custom-designed VLE, we aim to identify patterns that reflect student interest and interaction, addressing the question: How can spatial behavior analysis enhance VLEs to boost student engagement in classical poetry? Assuming spatial behaviors are indicators of engagement, we seek to validate these metrics for refining VLEs to stimulate and sustain interest in subjects like classical poetry. This approach aims to explore the potential of spatial behavior analysis in understanding student interactions and engagement within immersive educational experiences, offering insights that could inform the design and development of future VLEs.

2 Related Research

The advent of technologies like game engines and 360-degree cameras facilitated the creation of literature-focused virtual learning experiences. These experiences range from recreating the world of specific literary works, such as Colreavy-Donnelly's interactive 3D environment based on a chapter from James Joyce's Ulysses [1] and Powell's immersive VR simulation based on The Great Gatsby [9], to portraying authors using virtual technology, as seen in Gardner's immersive experience that lets students play the role of Elizabeth Barrett Browning's son's girlfriend [4]. Huang's use of a spherical video-based virtual reality experience to immerse students in the environment described in an article about climbing Jade Mountain [6] demonstrated the potential of these technologies to enhance students' writing performance and creativity.

While these applications of virtual technology hold potential for enhancing literacy skills and making literature more engaging, research into students' learning processes during virtual experiences remains limited. In particular, humanities subjects have fewer objective measures to gauge comprehension and critical thinking and, consequently, qualitative case studies have been commonly used. Steinkuehler [11] and Merchant [7] used participant observation, chat logs, interviews, and student work analysis to understand the literacy practices in games and the impact of virtual worlds on literacy learning. On the other hand, Patera [8] and Huang [6] employed mixed methods, comparing students' writings with and without virtual environments, and analyzing performance differences. They also used pre/post questionnaires and interviews to gather both quantitative and qualitative data.

Although these studies provided valuable insights into learning outcomes associated with the use of virtual technology, they have not fully captured the intricate processes that occur during the actual learning experience within these virtual environments. On the other hand, tracking the position and direction of users' heads (or camera) can be utilized to unobtrusively analyze factors such as social dynamics, interests, and engagement during the experience of virtual spaces [14,5]. This method allows for the collection of data from tens or even hundreds of thousands of users over several months in natural usage settings [3]. Williamson [14] utilized Mozilla Hubs as a platform to conduct an academic workshop. During this event, a "proxemic dataset" was compiled, encompassing the 3D positions of participants over time, in addition to the pairwise distances and angles between them. By integrating this quantitative tracking data with observational notes and interviews, Williamson was able to derive valuable in- sights into the social interactions and experiences that transpired during the virtual workshop.

In a similar vein, Harron et al. [5] conducted an investigation into students' gaze patterns during a virtual reality (VR) field trip in a science classroom. The researchers utilized tracking data to generate heatmaps, effectively visualizing the areas where students directed their attention throughout the VR experience. This was done both prior to and following an actual museum visit. The analysis of these patterns revealed significant differences in exploration behaviors. Notably, the authors found that students' exploration within the VR environment was somewhat constrained before the in-person museum visit, but it expanded considerably after the visit. This indicates for educators that VR could serve as a more effective tool for reinforcing learning when used subsequent to field trips, rather than as a precursor. These studies illustrate that the simple tracking of users' head positions and orientations can serve as an effective, scalable approach to gaining nuanced insights into engagement and learning behaviors in virtual educational settings.

3 Learning Materials for the Haiku Master's Journey

The virtual learning materials discussed in this article were designed for college students (n = 208, aged 18-22) majoring in information technology, who have limited knowledge of Japanese classical works and little experience using virtual spaces. Most of them have limited experience with using metaverse platforms like Mozilla Hubs. One of the central themes of this course was Matsuo Basho, a preeminent Haiku poet who composed numerous

Haikus during his travels across Japan, including the Yoshino area, which was the primary focus of this course. Prior to the virtual exploration, students engaged with selected texts of Basho as well as Edo period geographical records that mention Yoshino and its surroundings. These preparatory lessons aimed to familiarize students with Basho's journey and the significance of the locations he visited, setting a foundation for their virtual experiences. During the virtual exploration sessions, specific tasks were assigned to students to ensure an active engagement with the VLEs that directly related to the poetry and historical documents they had studied. For instance, students were tasked with identifying and photographing specific historical sites mentioned in Basho's works within the virtual Yoshino area. This task was designed to reinforce their understanding of the spatial relationships between these sites and their significance in Basho's poetry. Incorporating these virtual explorations into the curriculum, the students embarked on their virtual journeys in the final two lectures. Additionally, they were encouraged to utilize time outside of class, if necessary, to complete the assignments, ensuring ample opportunity for immersive learning and exploration.

For these lectures, we developed two types of VLEs that students accessed using PCs or VRHMDs. The first type centered on historical locations and artifacts related to Basho and Yoshino area. For example, Kokeshimizu (Moss Spring) is an ancient water spring with an inscribed stone monument featuring one of Basho's Haikus from his essay. To capture the intricacies of the monument and the general ambiance of its setting, we created a 3D model of the monument using LiDAR scans and took a 360-degree photograph of the location with the Polycam app on an iPad Pro. The inclusion of both the 3D model and the panoramic photograph was intended to provide students with a better understanding of the monument's structure and its surrounding environment. We positioned the 3D model between the spawning point in the virtual space and the monument's image in the 360-degree photo, ensuring that users first encounter the 3D model of the monument rather than the image in the photograph upon entering the room. We also implemented an invisible boundary to confine the area where users could walk. While the boundary was set to avoid breaking the immersion, users could also go beyond this boundary using the "fly mode." of Mozilla Hubs if they wanted to. Students visiting these virtual environments were encouraged to explore the area, closely examine the monument, and complete tasks such as photographing the monument. Students were asked to visit the virtual spaces of Kokeshimizu, then move to Yoshitsune Kakuretou (Yoshitsune's Sanctuary), and finally to Saigyo-an (Saigyo's Hermitage), all of which are linked to Basho's essays and Haikus. Due to page limitations, this paper will focus solely on Kokeshimizu, omitting results for Saigyo-an and Yoshitsune Kakuretou.

The second type of VLEs was dedicated to the Basho's journey. Within the Yoshino area, we identified several historical sites associated with his journey. We selected six locations: Kinpu Jinja (Kinpu Shrine), Yoshitsune Kakuretou, Anzen-ji (Anzen Temple), Shihou Shoumen-Do (Four-Faced Hall), Kokeshimizu, and Saigyo-an. We captured a 360-degree photograph at each site and integrated them into a 3D geographic model of the Yoshino area, which was generated using the 3D map service provided by the Geospatial Information Authority of Japan (https://maps.gsi.go.jp/). Students were tasked with journeying through the virtual environment, mirroring Basho's travels, with the aim of identifying locations that match the sites they studied in the historical documents covered during the lectures.

4 Analyzing Students' Behaviors in Virtual Spaces

In this study, we employed a modified version of the virtual learning system we previously reported. The original system utilizes Hubs Cloud Personal to create and host virtual spaces on Amazon Web Services (AWS). A custom script transmits user positions and rotations to Plausible, an open-source web analytics tool, as custom events. This dataset is subsequently downloaded to a Unity-based visualization app, which displays the virtual space and user log data. In the modified version, the app plots the position and direction using an arrowhead, where the color changes based on its horizontal direction (North: blue, East: khaki, South: red, West: green). This provides an intuitive understanding of the user's actions and movements, enabling researchers to quickly identify the user's behaviors within the virtual space.

Furthermore, the modified app also offers the clustering of students based on location data. Segmenting the data into several groups reduces data complexity and facilitates the analysis of each group's characteristics. In this application, we adopted K-means Clustering, which is widely used in the field of learning analytics [16]. K-means Clustering is based on measuring the distance (Euclidean distance) between data, under the assumption that the lengths of the data are equal. However, in our case, the length of the data varies significantly because the stay time in each room (i.e. instance of a virtual space) differs. Additionally, we were dealing with a large volume of data in each room and a large number of rooms, which would require substantial calculation time. Therefore, we decided to calculate the number of data points in specific regions (Regions of Interest, ROIs) in each room, and extract their ratios to the total counts as a feature. This reduces the number of data points in each room to the

number of ROIs, significantly decreasing the volume of data and making it easier to identify the features. ROIs are specified by rectangular objects (bound objects).

In practice, we first display all the data points on the analysis app and determine the number and location of the ROIs, primarily based on where the data points were concentrated. The app then calculates the number of data points for each of the ROIs for each room and processes the data into a specified number of clusters. Since K-means Clustering requires the number of clusters before calculation, the app also calculates the WCSS (Within Cluster Sum of Squares) during the cluster calculation, and we determined the appropriate number of clusters using the Elbow method [2]. More specifically, we plotted the WCSS against the number of clusters and identifying the point where the rate of decrease sharply changes, resembling an 'elbow.' This point signifies that adding more clusters does not significantly improve the fitting of the model, thus indicating the optimal number of clusters to use for K-means Clustering.

5 Results

5.1 Kokeshimizu (Moss Spring)

Fig. 1 presents top views (a, b) and a first person perspective (c) of the virtual space of Kokeshimizu. A Haiku monument was present in this space, and students were instructed to photograph it. Fig. 1a displays the positions of the 3D model and the image of the monument within the 360-degree photo, while Fig. 1b illustrates the plot of students' locations and rotations, along with Regions of Interest (ROIs). The right ROI (shown in red) is the area close to the image of the monument, while the small central ROI is situated near the 3D model of the monument. We also set up four ROIs along the floor boundaries. Overall, the arrows predominantly clustered around the 3D model of the monument, accounting for 56.4% of the data points. However, a significant number of arrows(40.1% of the data points) were located on the boundaries. The south boundary had the highest number, likely because it was closest to the image of the monument. A small number of arrows (3.5% of the data points) were found near the image of the monument, indicating the use of the fly mode to traverse the boundary and move closer to the image of the monument.

Next, the data was segmented into four clusters using K-means Clustering (Fig. 2). In the largest cluster (102 entries, Fig. 2a), students were found to explore mostly around the 3D Haiku monuments. In the second cluster (41 entries, Fig. 2b), on the other hand, students were observed spending significant time on the floor boundaries, particularly the southern border. The third cluster (39 entries, Fig. 2c) demonstrated a group of students' efficient use of the fly mode, as the data points were primarily found near the 360-degree image of the monument. In the smallest cluster (24 entries, Fig. 2d), students seem to have spent little time near the monument, possibly due to difficulty locating it.

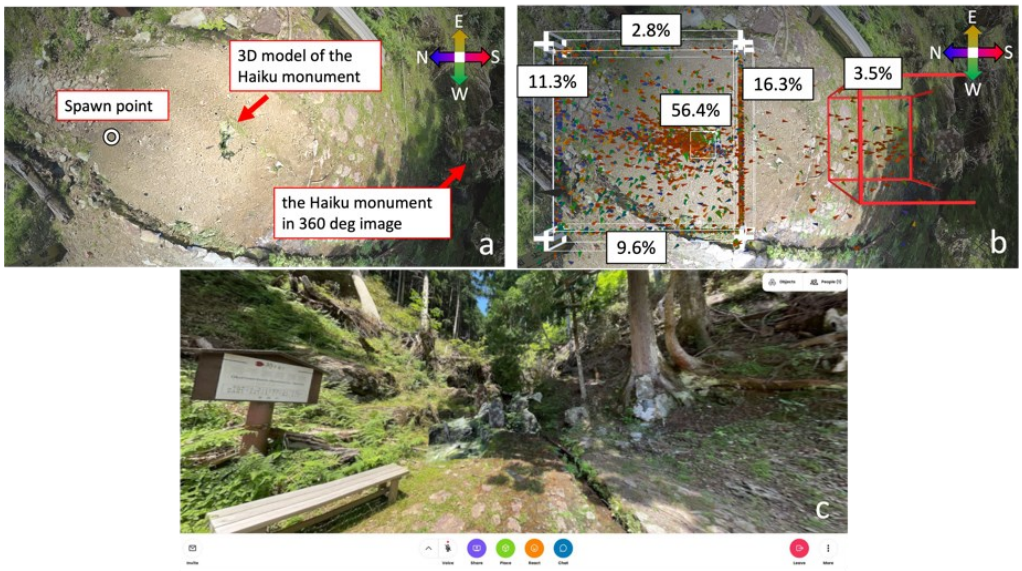

Fig. 1. The virtual space of Kokeshimizu (Moss Spring) with student interaction data. (a) Positions of the 3D model of the Haiku monument and the image of the monument within the 360-degree photo. (b) Plot of students' locations and rotations. White outlines indicate regions of interest (ROIs). Percentages represent the proportion of data points in each ROI. The compass on the top right of each image indicates cardinal directions: North (N), West (W), South (S), and East (E).}. (c) An example of a first-person perspective within the virtual environment of Kokeshimizu.

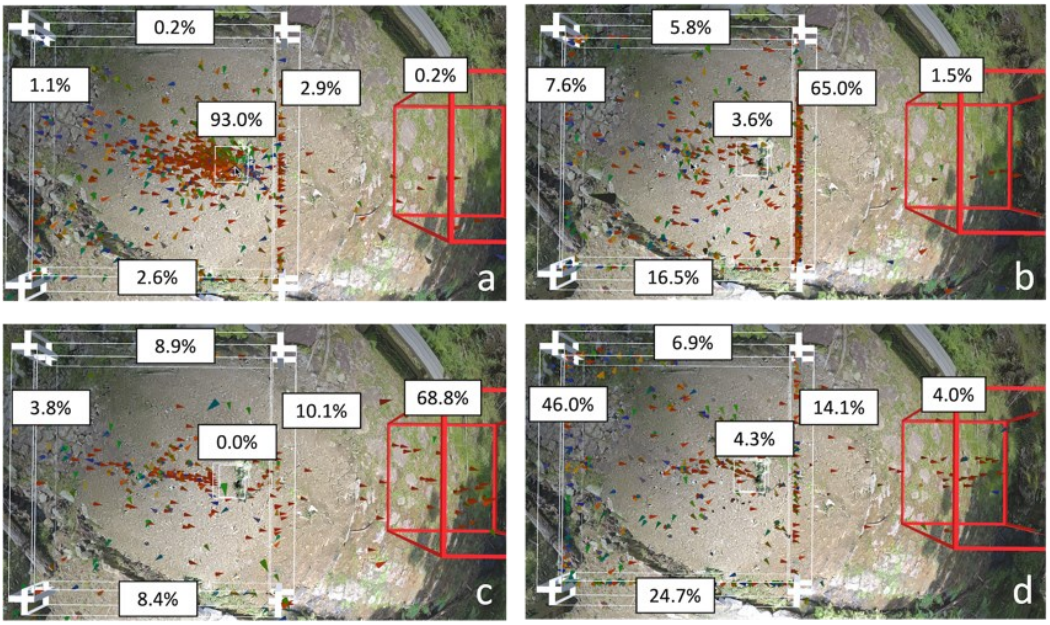

Fig. 2. K-means Clustering of student data from Kokeshimizu. White and red outlines indicate regions of interest (ROIs). Percentages represent the proportion of data points in each ROI. (a-d) Clusters ordered by size.

5.2 Basho's Journey

Unlike the "Kokeshimizu" virtual space, "Basho's Journey" features six 360- degree photos of Basho-related historical sites placed on a geographical 3D model (Fig 3, a). In the assignment, students were required to visit three specific sites (Kokeshimizu, Shiho Shoumen-do, Kinpu Jinja) and correctly identify them using the provided handouts and information within the virtual space. Starting from the southern end of the virtual space, students seem to have navigated northward (as indicated by the blue arrows) to visit the initial two sites and ventured further to explore other locations (Fig 3, b). The multicolored arrows between the sites suggest that students moved back and forth to accomplish their tasks.

Regions of Interest (ROIs) were set up for each of the 360-degree photos (Fig 3 right). Kinpu Jinja was the most frequented site (46.0%). Despite being adjacent to Kinpu Jinja, Yoshitsune Kakuretou received significantly fewer visits (3.2%). The other two mandatory sites also received a substantial number of visits (Kokeshimizu: 19.7% and Shihou Shoumen-do: 18.1%).

The data was partitioned into four clusters by K-means Clustering, yielding two larger and two smaller clusters (Fig 4). In the largest cluster (n=76), students dedicated a substantial amount of time at Kinpu Jinja (78.0%), significantly more than at other required sites (Shihou Shoumen-Do: 7.2%, Kokeshimizu: 8.8%). The second largest cluster (n=73) showed a different pattern, with students spending the majority of their time at Kokeshimizu (52.8%) compared to the other two required sites (Kinpu Jinja: 17.3%, Shihou Shoumen-Do:14.7%). In contrast, students in the third largest cluster (n=40) primarily visited sites not required for the assignment (Yoshitsune Kakuretou: 15.0%, Anzen-ji: 51.0%, Saigyo-an: 24.1%). Finally, students in the smallest cluster (n=35) spent the majority of their time at Shihou Shoumen-do (70.4%).

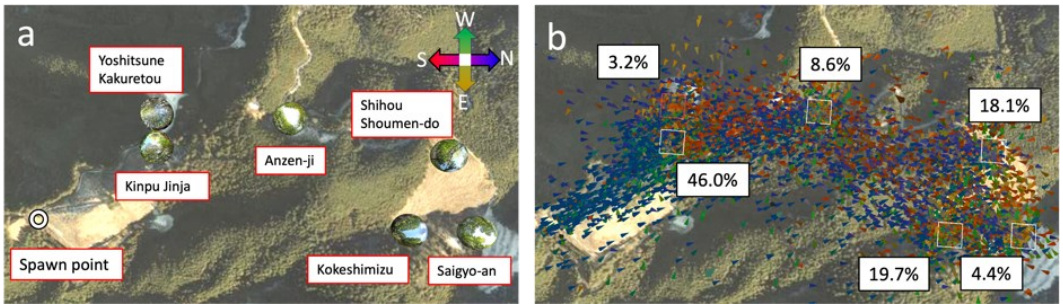

Fig. 3. Virtual space of 'Basho's journey': (a) top view, (b) top view with students' locations, rotations, ROIs, and the percentages of the data points in ROIs. In (b), the 360-degree photos are omitted to reveal the markers inside the spheres.

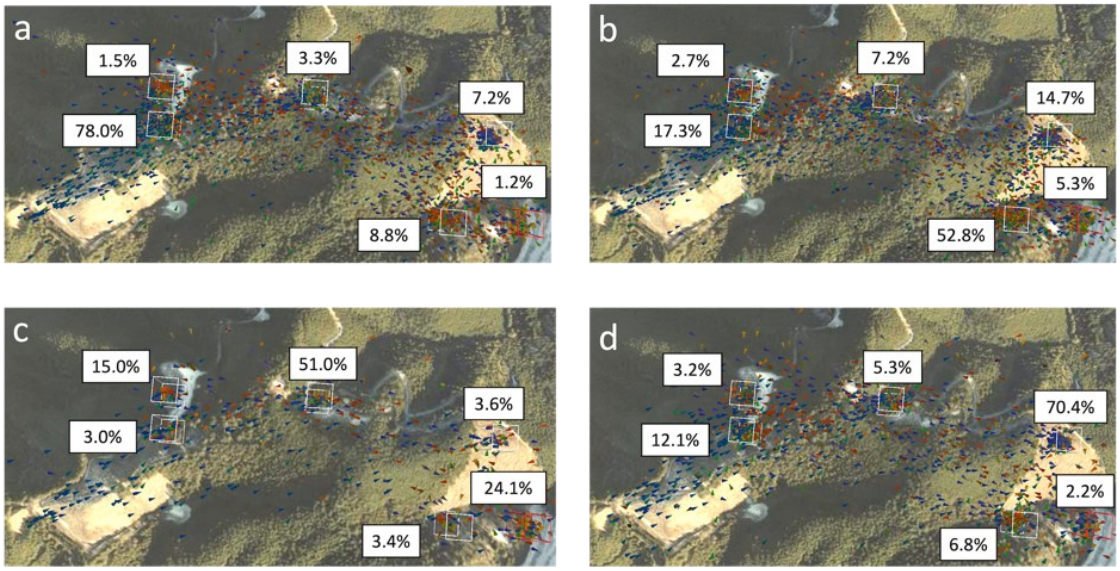

Fig. 4. K-means Clustering of student data from "Basho's journey". (a-d) Clusters ordered by size.

6 Discussion

This study analyzed the spatial behavior patterns of students during an immersive virtual learning experience of the Haiku master's journey. The clustering of data points around the 3D model of the Haiku monument in Kokeshimizu, suggests a strong focal point of interest among the majority of the students. This is further supported by the largest cluster identified through K-means Clustering, where a significant portion of students concentrated their exploration around the 3D Haiku monuments. This behavior was probably due to its central placement or the specific assignment task to photograph it, underscoring the importance of strategically positioning key educational elements within a virtual space to guide student engagement and focus. The insights gained from analyzing spatial behavior patterns in VLEs could potentially be applied to real-world field trips, guiding the design of educational activities and the placement of key learning elements to optimize student engagement and learning outcomes.

The observation of a substantial number of data points along the area boundaries suggests a pattern of exploration beyond the immediate vicinity of the central task. The second cluster highlights this behavior, indicating a group of students who were possibly more explorative or who might have been seeking different perspectives of the virtual environment. The efficient use of the fly mode by the third cluster to approach the 360-degree image of the monument represents an even stronger explorative pattern. These students, with a higher level of engagement and technical skill in navigating the virtual space, may represent a more inquisitive subset who are willing to experiment with the tools available to them to enhance their learning experience. On the other hand, the smallest cluster, where students spent little time near the monument, raises questions about the challenges some learners may face in virtual environments. This could be due to difficulties in locating the monument or a lack of engagement with the task. It highlights the diversity in student experiences within virtual learning environments and the need for designing these spaces and tasks to accommodate different learning styles and preferences.

The data from "Basho's Journey" virtual space exploration provides insightful patterns on how students interacted with the educational content, revealing varied engagement levels with the historical sites. The most frequented site, Kinpu Jinja, attracted a significant portion of the student visits, with the largest cluster of students spending a considerable amount of time there. This could indicate that Kinpu Jinja, being a mandatory site and possibly due to its proximity to the spawn point, was perceived as an essential part of the learning experience. The contrast in visitation patterns between Kinpu Jinja and adjacent sites like Yoshitsune Kakuretou, which received significantly fewer visits, might reflect the students' focus on assignment requirements over exploratory learning. This focused approach is further supported by the substantial visits to the other two mandatory sites, Kokeshimizu and Shihou Shoumen-do, indicating that students prioritized the completion of their tasks over the exploration of non-mandatory sites.

The second largest cluster's preference for spending more time at Kokeshimizu could be attributed to its introduction as the first task in the handout, suggesting that initial tasks in a sequential learning environment might receive more attention and effort from students. This finding could have implications for how educators structure and order content in virtual learning environments to maximize student engagement and learning outcomes. Interestingly, the third largest cluster's primary engagement with non-required sites suggests a subset of students were either more exploratory in their learning approach or perhaps experienced confusion regarding the assignment requirements. This behavior underscores the importance of clear guidance and signposting in virtual learning environments to ensure students can effectively navigate and engage with the intended content. Finally, the significant time spent at Shihou Shoumen-do by the smallest cluster, despite its lack of historical monuments or buildings, might indicate challenges in navigation or content interpretation at this site. This observation, coupled with the overall movement patterns, suggests that while most students followed a logical path through the virtual space, the design and clarity of the learning environment could impact their ability to engage effectively with the content.

7 Conclusion

This study's exploration into the use of immersive virtual learning environments (VLEs) for engaging students with the classical poetry form of Haiku has demonstrated the potential of spatial behavior analysis as a tool for enhancing educational experiences. By examining the movements and orientations of students within a VLE designed around the journey of a Haiku master, we have identified patterns of engagement that suggest the importance of strategic content placement, clear guidance, and support for diverse learning styles. These findings underscore the necessity of designing VLEs that not only accommodate focused task completion but also encourage exploration, thereby catering to a broad spectrum of learner preferences. Future studies could explore student engagement and learning outcomes within comprehensively detailed 3D models, potentially yielding more nuanced findings that are less constrained by the limitations of 360-degree environments.

Finally, it is important to acknowledge the limitations of this study, particularly its reliance on purely quantitative spatial behavior data. Future research should aim to integrate qualitative components, such as questionnaires or short interviews, to capture students' subjective experiences. This approach will enable a deeper understanding of the motivations behind observed behaviors, leading to more refined and nuanced interpretations of spatial analysis findings. By addressing these limitations and building on the insights gained, educators can further tailor VLEs to effectively stimulate interest and engagement in subjects like Haiku, thereby enriching the learning experience for students in humanities education.

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References

1. Colreavy-Donnelly, S.: I-Ulysses: poetry in motion. An educational virtual reality guide to the unfolding events of the 'Wandering Rocks' chapter of Joyce's Ulysses. Ph.D. thesis, University of Galway (2016).
2. Cui, M.: Introduction to the k-means clustering algorithm based on the elbow method. Clausius Scientific Press 1, 5–8 (2020).
3. Drachen, A., Canossa, A.: Towards gameplay analysis via gameplay metrics. In: Proceedings of the 13th International MindTrek Conference: Everyday Life in the Ubiquitous Era. pp. 202–209. Association for Computing Machinery (2009).

4. Gardner, A.M.: An Exploratory Case Study on the Pedagogical Possibilities of Educational Cinematic Virtual Reality in High School English Classes. Ph.D. thesis, Baylor University (2022).
5. Harron, J.R., Petrosino, A.J., Jenevein, S.: Using virtual reality to augment museum-based field trips in a preservice elementary science methods course. Contemporary Issues in Technology and Teacher Education 19, pp. 687–707 (2019).
6. Huang, H.L., Hwang, G.J., Chang, C.Y.: Learning to be a writer: A spherical video-based virtual reality approach to supporting descriptive article writing in high school chinese courses. British Journal of Educational Technology 51(4), pp. 1386–1405 (2019).
7. Merchant, G.: Literacy in virtual worlds. Journal of Research in Reading 32, 38–56 (2009).
8. Patera, M., Draper, S., Naef, M.: Exploring the magic cottage: A virtual reality environment for stimulating children's imaginative writing. Interactive Learning Environments 16, pp. 245–263 (2008).
9. Powell, A.R.: Frankenstein's Monster at Gatsby's Party: A Researcher's Creation of and Entanglement with Virtual Reality Let Loose in a High School English Classroom. Ph.D. thesis, Tennessee Technological University (2020).
10. Roth, W.M., Nguyen, H.N.G.: An analysis of haiku teaching discourse: From talking about to doing haiku. Journal of Pedagogical Research 3, 113–125 (2019).
11. Steinkuehler, C.: Massively multiplayer online gaming as a constellation of literacy practices. In: The design and use of simulation computer games in education, vol. 4, pp. 187–215. Brill (2007).
12. Su, Y., Backlund, P., Engström, H.: Comprehensive review and classification of game analytics. Service Oriented Computing and Applications 15, pp. 141–156 (2021).
13. Tweedie, S., Kolitsky, M.A.: 3-d haiku: A new way to teach a traditional form. The English Journal 91 (2002).
14. Williamson, J.R., Li, J., Vinayagamoorthy, V.: Proxemics and social interactions in an instrumented virtual reality workshop. In: Proceedings of the 2021 CHI conference on human factors in computing systems. pp. 1–13 (2021).
15. Yano, K.: A platform for analyzing students' behavior in virtual spaces on mozilla hubs. In: M., J., Daniela, P., Andreas, D., Anasol, P.R., Marie-Luce, R.J.B., Krüger (eds.) Immersive Learning Research Network. pp. 209–219. Springer Nature Switzerland (2024).
16. Yunita, A., Santoso, H.B., Hasibuan, Z.A.: Research review on big data usage for learning analytics and educational data mining: A way forward to develop an intelligent automation system. In: Journal of Physics: Conference Series. vol. 1898, p. 012044. IOP Publishing (2021).