

GeoConnect: An Immersive VR Game for Learning Brazilian Geography

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Abstract. *GeoConnect is an educational VR game designed to support the development of cartographic skills through an immersive and interactive experience. Aligned with the competencies outlined in the BNCC, the game introduces progressively challenging puzzle stages focused on assembling the Brazilian map. Players interact with floating pieces using snapping mechanics, with multimodal feedback (visual, auditory, and haptic) reinforcing spatial learning. The objective of this work is to present the first version of GeoConnect and to evaluate its usability through a simplified structure that includes a 360° exploration mode for each completed region. The results indicate that the system successfully met its objective, delivering a functional prototype capable of supporting cartographic learning in an engaging way.*

1. Introduction

Cartographic literacy in the early years of elementary school is essential for the development of students' ability to interpret and represent the space around them [Tenório et al. 2025]. Maps are described by Simielli as a true “reading of the world”, condensing geographical phenomena into meaningful visual representations [Simielli 1996]. In this regard, the Brazilian National Common Curricular Base (BNCC) emphasizes fundamental competencies such as map reading, understanding scales, and using coordinate systems, with the goal of promoting cartographic autonomy [BRASIL, Ministério da Educação 2017]. However, traditional methodologies centered on rote memorization often result in low engagement and a superficial understanding of the territory [Pontes and Rodrigues 2022].

Research demonstrates that active methodologies and the use of interactive technologies, particularly through gamification, elevate levels of motivation, participation, and academic performance [Zainuddin et al. 2020]. When combined with the immersion provided by Virtual Reality (VR), these approaches favor content retention and the development of spatial mental models by allowing for the direct manipulation of geographical objects in three-dimensional environments [Lampropoulos and Kinshuk 2024, Hamdan et al. 2024]. Recent studies further indicate that the combination of gamification and VR is perceived by students and teachers as more attractive and effective than conventional methods [Wu et al. 2020].

Building on these findings, several other studies reinforce that VR significantly enhances educational outcomes, particularly by increasing student engagement, knowledge retention, and the effectiveness of spatial learning. For instance, a meta-analysis found that immersive VR yields stronger learning gains than traditional or less immersive methods across diverse subject areas, including geography [Coban 2022]. Similarly, another study on VR applications in geography education concluded that, although its adoption remains limited, VR offers a proactive and effective approach to teaching geographical concepts, enhancing motivation and interaction [Czimre 2024].

Numerous platforms utilize gamification in geography education, such as *Seterra*, a program offering dozens of interactive geography exercises focusing on identifying countries, capitals, and flags [Wikipédia contributors 2025b], and *GeoGuessr*, a game that challenges players to infer their location based on Google Street View imagery and has been recognized as an educational tool that enhances geographical and cultural landscape understanding [Wikipédia contributors 2025a]. Other systems, like *Google Earth VR*, provide immersive exploration experiences through virtual reality environments [Google VR Team 2025]. However, these solutions do not allow for the direct manipulation of cartographic pieces with physical-virtual fitting mechanisms, nor are they explicitly aligned with BNCC competencies, highlighting a gap in both the market and the specialized literature.

In this context, we propose *GeoConnect*, an educational virtual reality game that recreates the traditional activity of assembling the map of Brazil through an interactive and immersive approach. The system uses cartographic puzzles with progressive difficulty, complemented by visual, auditory, and haptic feedback. This design is aligned with the competencies of the BNCC, offering a playful and contextualized learning experience focused on the development of spatial reasoning, such as:

- **Competency 1** – Use geographical knowledge to understand the interaction between society and nature, while fostering inquiry, investigation, and problem-solving skills.
- **Competency 2** – Establish connections between different themes of geographical knowledge, recognizing how natural resources have been historically used by societies.
- **Competency 3** – Develop autonomy and critical thinking in the application of geographical reasoning, involving principles such as analogy, connection, differentiation, distribution, extension, location, and order.
- **Competency 4** – Develop spatial thinking by employing cartographic and iconographic languages, textual genres, and geotechnologies to solve problems that involve geographical information.
- **Competency 5** – Employ investigative processes, practices, and procedures to understand the natural, social, economic, political, and techno-scientific world, while proposing solutions to geographical issues.

The *GeoConnect* proposal — with interactive cartographic puzzles, multimodal feedback, and progressive difficulty — directly addresses these competencies, promoting their development in a playful, contextualized, and BNCC-aligned way.

2. Objectives

This project aims to develop an educational VR game, named GeoConnect, focused on teaching basic cartographic concepts to middle school students. The goal is to provide an interactive and immersive experience that stimulates interest in geography. Through the assembly of maps and the exploration of geographical elements of the Brazilian territory, the game seeks to reinforce core concepts in a playful and accessible way, making learning both engaging and effective.

3. Materials and Methods

The game was developed using Unity version 2022.3.24f1, incorporating the XR Interaction Toolkit, which enabled the implementation of virtual reality interactions compatible with multiple immersive display devices (HMDs). For functionality and usability testing, the Meta Quest was used, configured with a hybrid control scheme that combines hand tracking and physical controllers. The project adhered to principles of code organization and clarity, adopting functionally structured scripts that are easy to maintain and designed to support future system extensions.

The 3D modeling of the Brazilian territory, including the division into regions and federative units, was carried out in Blender, ensuring the spatial accuracy of each manipulable piece. The virtual classroom environment was assembled using .fbx models obtained from Sketchfab, all under educational-use licenses, thereby ensuring both visual quality and legal compliance.

4. Educational Game

Considering this context, GeoConnect incorporates a game mechanic focused on snapping-based challenges. In each stage, the user interacts with a structural representation of the Brazilian territory, accompanied by floating pieces that remain visible within the field of view, allowing for the simultaneous identification of the base map and the elements to be positioned.

When launching the application, the user is greeted by a main menu with options to start the game, directly select a specific stage, or exit the experience. Choosing “Start Game” takes the user to a secondary menu, where they can either complete an introductory tutorial or proceed directly to Stage 1. If the tutorial is selected, the user is guided through a scene that explains the controls and snapping mechanics, and upon completion, is automatically redirected to the beginning of the game. If the user chooses to skip the tutorial, the system takes them straight to the first stage.

Each stage presents the player with a specific objective, which involves correctly positioning the pieces using the snapping mechanism. Upon successfully completing the task, a confirmation screen is displayed before the system automatically transitions to the next stage. This cycle repeats throughout the first two stages. After completing Stage 3, a final menu appears, offering the user the option to restart the game (returning to Stage 1) or go back to the main menu.

Alternatively, by selecting the “Select Stage” option in the main menu, the user is taken directly to the chosen stage. Upon completing it, they may choose to continue to another stage or end the session using the same navigation menu. Figure 1 illustrates the

main interaction flow of GeoConnect, which was implemented in the first version of the game.

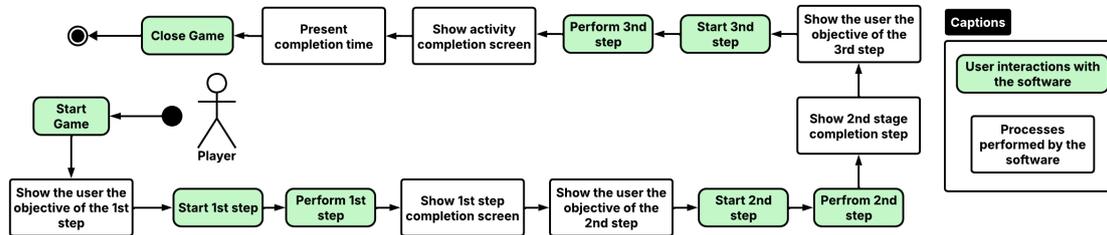


Figura 1. Main Interaction Flow

To enhance user immersion, GeoConnect leverages hand tracking on devices that support this feature, while remaining fully compatible with traditional controllers. To prevent disorientation during piece manipulation, rotation along the Z axis is entirely locked, and controlled constraints are applied to the X and Y axes to ensure that the objects maintain their original orientation consistent with the map. After each step, the application presents a completion panel inviting the student to explore a 360° immersive scene related to the completed region, featuring key landscapes, cities, and landmarks to enhance engagement and learning.

When a piece is correctly positioned, the system automatically snaps it to the target mesh and highlights it with a green glow to indicate successful placement. Conversely, if the piece is placed incorrectly, it is outlined in red, returned to its original position, and a brief audio cue is played. This combination of visual and auditory responses functions as multimodal feedback, supporting the assimilation of game mechanics and spatial learning without compromising the fluidity of interaction.

In the first version of GeoConnect, as illustrated in Figure 2, only the main stages of the game were implemented, with the goal of testing the application’s usability. The user begins directly in the virtual room where the map assembly activity takes place. Upon completing each stage, a transition menu is displayed, indicating that the phase has been completed and offering two options: “Continue” or “Explore”. If the user chooses to explore, they are teleported to an immersive 360° environment thematically related to the geographical region of the completed stage. Alternatively, by selecting “Continue” the user returns to the main activity to proceed with the game.

At the end of the three stages, a closing screen is displayed, indicating that the user has completed GeoConnect and showing the total time taken to complete the experience.

5. Conclusions

In summary, GeoConnect combines tiered cartographic puzzles, haptic and auditory feedback, and gradually increasing complexity, all within a virtual reality environment. This approach aligns with the cartographic competencies outlined in the BNCC, aiming to transform map assembly into an engaging and immersive learning experience. The objective of this study was to design and implement the first version of GeoConnect, focusing on testing its usability and alignment with curricular competencies. This goal was achieved with the development of a functional prototype capable of delivering interactive map

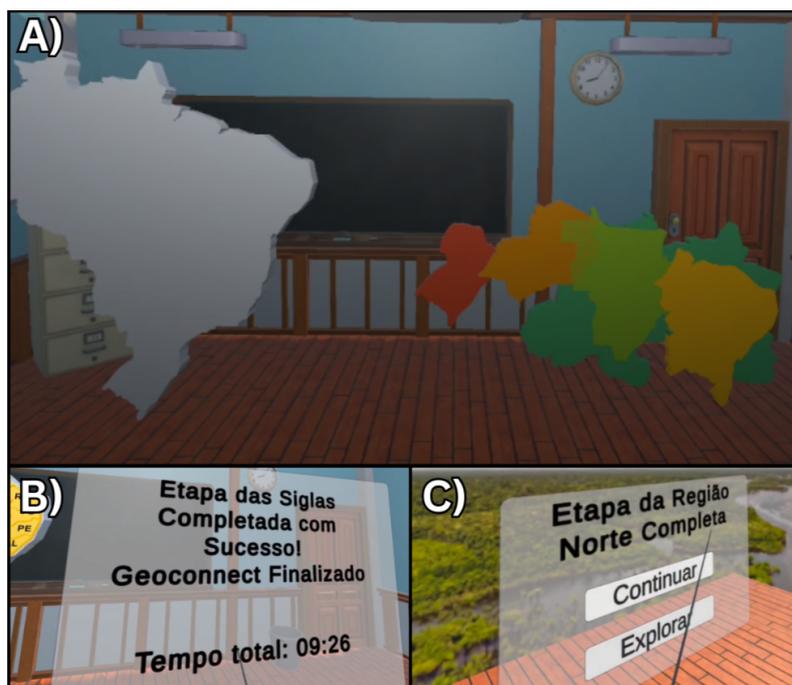


Figura 2. Scenes from the first version of the game

assembly activities and multimodal feedback mechanisms.

Preliminary evaluations with five adult volunteers confirmed the safety and usability of the system prior to testing with school-age students. Using the iUXVR questionnaire [Cheiran et al. 2025], participants rated the experience positively for its playful and educational character, while also reporting issues such as dizziness related to locomotion and suggesting improvements in instructions, map details, and interaction design.

As future work, GeoConnect will be expanded with performance metrics such as completion time, accuracy, and number of attempts. A tutorial explaining the game mechanics will also be implemented, as well as a mode in which users can select the stage they wish to play. Accessibility features for color-blind users will be included. To validate the game, tests will be conducted with the target audience, using questionnaires to assess usability, discomfort, and user experience. These evaluations will strengthen the validation of GeoConnect as an effective tool for teaching cartography.

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