Chapter 13
Bilingual Language Development for Atypically Developing Students Supported by Augmented Reality and Museum Kits

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ABSTRACT

Bilingualism, shaped by globalization and migration, is a growing focus in educational research. While typically developing bilingual students often demonstrate cognitive and linguistic benefits, those with atypical development, such as learning difficulties or socio-emotional challenges, face persistent barriers to language acqui-

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sition and communication. Addressing these needs requires inclusive, multisensory approaches. This study explores how museum kits, portable educational tools with cultural content and interactive materials, combined with augmented reality (AR), can support bilingual language development. It presents "Discover Corfu Old Town" (DisCot), a web-based AR application paired with a physical museum kit to create an experiential learning environment. Developed with open-source tools for mobile devices, DisCot prioritizes accessibility and scalability. Findings suggest that AR-enhanced museum kits may function as effective transmedia resources that foster language development, cognitive engagement, and inclusive educational practices for atypically developing students

1. INTRODUCTION

Bilingualism is a multifaceted phenomenon that intersects with disciplines such as sociolinguistics, psychology, and education. In an era marked by globalization, digital connectivity, and continuous migratory flows, the coexistence of multiple linguistic codes has become increasingly common. Language, as both a cognitive and social tool, plays a central role in identity construction and intercultural communication across diverse contexts (Potapova & Pruitt-Lord, 2020). Traditionally, bilingualism refers to the use of two distinct languages, with varying degrees of fluency and dominance. The first language (L1), typically acquired in early childhood, may diminish in prominence due to environmental or sociocultural influences, particularly among immigrant populations (Duff, 2019). The typology of bilingualism includes dominant, balanced, functional, and subtractive forms, each reflecting different patterns of language use and acquisition (Griva & Stamou, 2014). While bilingualism is often associated with cognitive benefits, such as enhanced executive function and metalinguistic awareness (Bialystok & Barac, 2012), it can also present challenges, particularly in vocabulary development and code-switching. These challenges are amplified in atypically developing students, including those with learning disabilities, neurodevelopmental disorders, or socio-emotional difficulties (Zhang & Wang, 2023).

Multisensory approaches, grounded in the principles of Universal Design for Learning (UDL) and Differentiated Instruction (DI), have proven effective in addressing diverse learning needs (Kaimara, 2023). By engaging multiple sensory modalities -visual, auditory, and kinaesthetic- these methods enhance comprehension, reduce cognitive load, and foster deeper engagement. Technological tools such as speech-to-text systems, gamified educational apps, and interactive whiteboards further support inclusive learning environments. Among these tools, museum kits stand out as portable, curated educational resources that combine tangible artifacts

with structured learning activities. When paired with emerging technologies like augmented reality (AR), museum kits evolve into dynamic transmedia platforms that promote experiential and culturally grounded learning (Poulimenou et al., 2023).

AR offers immersive, interactive experiences that blend physical and digital content, enabling learners to explore historical narratives, simulate real-world scenarios, and engage in role-playing activities. These affordances are particularly valuable for bilingual learners, as they support both linguistic and cognitive development and metacognitive awareness through contextualized, multimodal interaction (Geng & Yamada, 2025). Despite the growing interest in AR and museum-based learning, limited research has explored their combined impact on bilingual students with atypical development.

This chapter investigates whether the integration of AR and museum kits can facilitate language development among bilingual learners with diverse educational needs. It presents the design and development of the "Discover Corfu Old Town" (DisCot) application, an AR-enhanced educational game set in Corfu Old Town, utilising open-source technologies and cost-effective hardware. The application merges physical museum kits with digital storytelling and gameplay mechanics. The goal is to create an inclusive, engaging, and culturally rich learning experience. A comprehensive evaluation framework will assess the application's usability, educational impact, and potential for broader adoption.

The chapter is structured as follows: it begins with a theoretical overview of bilingualism in atypical language development, followed by a discussion of multisensory and inclusive approaches to language learning. It then explores the educational value of museum kits and the pedagogical potential of AR in cultural learning. Building upon this theoretical foundation, the chapter presents a detailed case study of the "DisCot" application, an AR-enhanced museum kit, culminating in an evaluation of its effectiveness and a discussion of future research directions.

2. THEORETICAL FRAMEWORK

2.1. Bilingualism in Atypical Language Development

Bilingualism, broadly defined as the use of two linguistic codes, is a dynamic and context-dependent phenomenon. While typically developing bilingual students often benefit cognitively and linguistically from structured exposure to two languages, the same cannot be assumed for students with atypical development. These learners, who may experience cognitive, sensory, or socio-emotional challenges, require tailored educational approaches to support their language acquisition and overall growth. The typology of bilingualism includes dominant, balanced, functional, and subtractive

forms (Griva & Stamou, 2014), each of which may interact differently with atypical developmental profiles. For instance, children with neurodevelopmental disorders often face difficulties in phonological processing, working memory, or syntactic comprehension, which are foundational to bilingual language development. These challenges may manifest as trouble following multi-step instructions or processing new vocabulary during learning activities. Despite early concerns that bilingualism might exacerbate such difficulties, contemporary research suggests otherwise. In many cases, bilingualism does not hinder and may even support cognitive and linguistic development in atypical learners (Paradis, 2023). Specific conditions illustrate the relationship between bilingualism and atypical development:

- *Developmental language disorder* (DLD): Children with DLD exhibit deficits in vocabulary, syntax, and phonology. While pseudoword repetition tasks often reveal limitations in phonological memory, bilingual children with DLD perform comparably to their monolingual peers and may develop compensatory strategies (Boerma & Blom, 2020).
- *Dyslexia*: Bilingual individuals with dyslexia may adopt different reading strategies across languages. Studies indicate that bilingualism can enhance phonological awareness and even support reading development in the first language when the second language has simpler phonological structures (Vender & Melloni, 2021).
- *ADHD*: Research indicates that bilingualism does not negatively impact children with ADHD. In some cases, it may correlate with reduced behavioral symptoms, particularly when language proficiency is high (Köder et al., 2022; Sharma et al., 2022).
- *Autism spectrum disorder* (ASD): Contrary to earlier assumptions, bilingual exposure does not worsen communication difficulties in children with ASD. Instead, it may enhance executive function and linguistic flexibility (Davis et al., 2022).
- *Hearing Impairments*: Although concerns exist about bilingualism complicating oral language development in children with hearing loss, studies show that bilingual interventions, especially with strong family involvement, can lead to improved outcomes (Müller et al., 2020).
- *Down syndrome*: Despite significant morphosyntactic challenges, bilingual children with Down syndrome can achieve comparable levels of expressive and receptive language skills to their monolingual peers, provided they receive consistent exposure (Katsarou & Andreou, 2021).

These findings highlight that bilingualism, when supported by tailored and inclusive pedagogies, constitutes a significant asset rather than a hindrance for atypical

learners. Rather than viewing bilingualism as a risk factor, educators and clinicians are increasingly recognizing its potential as a cognitive and communicative asset, especially when supported by inclusive, multisensory, and culturally responsive pedagogies. Recognizing this interplay between bilingualism and atypical development calls for pedagogical practices that are not only inclusive but also capable of activating multiple sensory pathways to foster meaningful language acquisition.

2.2. Multisensory and Inclusive Approaches to Language Learning

Inclusive education aims to address the diverse needs of all learners by removing barriers to learning and participation. For bilingual students with atypical development, this requires pedagogical strategies that are both flexible and responsive to individual learning profiles. Multisensory approaches have emerged as particularly effective in this context, as they engage multiple sensory modalities (visual, auditory, kinesthetic, and tactile), enhancing comprehension, memory, and motivation (Freeman-Green et al., 2023). For example, students with auditory processing difficulties may benefit from visual supports such as subtitles or graphic organizers, while those with dyslexia may find speech-to-text and text-to-speech tools helpful for decoding and encoding language (Kaimara, Deliyannis et al., 2021). Kinesthetic activities, such as building models or using manipulatives (e.g., reconstructing historical buildings or labeling parts of a physical artifact), can support conceptual understanding and language development, particularly in students with attention or executive function challenges. These strategies align closely with the principles of UDL and DI. UDL promotes the provision of multiple means of representation, engagement, and expression, ensuring that all students can access and demonstrate understanding in ways that suit their strengths (CAST, 2018). DI, on the other hand, emphasizes the adaptation of content, process, and product based on students' readiness, interests, and learning profiles (Tomlinson et al., 2003). Building upon these principles, emerging technologies offer new avenues for multisensory learning.

Technological advancements have significantly expanded the possibilities for implementing multisensory and inclusive practices. Interactive whiteboards, gamified educational apps, and adaptive learning platforms offer dynamic and personalized learning experiences. These tools not only support students with learning difficulties but also enhance the educational experience for all learners by fostering engagement, autonomy, and collaboration (Kaimara, 2023). Importantly, inclusive approaches must be embedded within a broader pedagogical framework that values diversity and promotes equity. Personalized learning plans, collaborative group work, and culturally responsive teaching are essential components of such a framework. For bilingual students with atypical development, these strategies can bridge linguistic

and cognitive gaps, enabling them to access the curriculum meaningfully and participate fully in the learning process (García & Lin, 2016).

In sum, multisensory and inclusive approaches are not only beneficial but necessary for supporting bilingual learners with diverse needs. When thoughtfully implemented, they create a learning environment where all students, regardless of ability or background, can thrive.

2.3. Educational Museum Kits and their Relevance to Atypically Developing Bilingual Students

Museum education, as a branch of cultural pedagogy, offers a dynamic and inclusive framework for learning that transcends traditional classroom boundaries. Museum kits, portable, curated educational units, are designed to bring the museum experience into schools and other learning environments. These kits typically include replicas of artifacts, maps, audiovisual materials, educational games, and printed or digital content, all tailored to specific learning objectives and age groups. Their multisensory and exploratory nature makes them particularly suitable for bilingual students with atypical development, who benefit from hands-on, contextualized, and differentiated learning experiences. Museum-pedagogical practices emphasize active participation, the transformation of information into personal meaning, and the creation of memorable learning experiences (Poulimenou et al., 2023). These principles align closely with inclusive education, as they support both individual and social dimensions of learning in a culturally rich environment. For bilingual learners with learning difficulties, such as dyslexia, ADHD, or developmental language disorder, museum kits offer an alternative pathway to language acquisition through experiential and multimodal engagement.

Recent advancements in educational technology have further enhanced the potential of museum kits. The integration of AR and digital educational games transforms these kits into transmedia learning platforms that promote discovery, interaction, and cultural immersion. The pedagogical effectiveness of these tools is grounded in a robust theoretical framework that draws from multiple learning theories (Poulimenou et al., 2023):

- Behaviorism emphasizes structured feedback and reinforcement. AR applications and gamified museum activities provide learners with immediate responses, rewards, and progress tracking, which enhance motivation and engagement (Deterding et al., 2011; Kaimara, 2023; Plass et al., 2015).
- Constructivism and social constructivism highlight the importance of active, experiential learning and social interaction. Learners construct knowledge through hands-on exploration of cultural artifacts and collaboration with

peers, aligning with Vygotsky's (1978) emphasis on the social nature of learning.

- Activity theory focuses on the context of learning, including the tools, goals, and social dynamics involved. Museum kits, especially when enhanced with AR, simulate real-world cultural activities and promote meaningful engagement (Engeström, 2009).
- Discovery learning, as proposed by Bruner (1961), encourages learners to explore, experiment, and draw conclusions independently. Museum kits support this approach by allowing students to uncover historical narratives and cultural meanings through inquiry-based tasks, aligning with pedagogical principles that emphasize culturally grounded, exploratory learning (Darling-Hammond et al., 2023).
- Gamification incorporates game elements- such as points, challenges, and leaderboards- into educational experiences. These elements increase motivation and reduce the fear of failure, creating a safe and engaging learning environment (Deterding et al., 2011).
- Transmedia storytelling uses multiple media formats (e.g., flashcards, maps, videos, social media) to create immersive and personalized learning journeys. This approach supports inclusive, student-centered learning and continuous knowledge construction (Herr-Stephenson et al., 2013).

By integrating these pedagogical principles, museum kits become powerful tools for inclusive bilingual education. They offer atypically developing bilingual students opportunities to engage with language and culture in ways that are meaningful, accessible, and enjoyable. Moreover, their adaptability supports differentiated instruction and aligns with the principles of UDL (CAST, 2018). When thoughtfully designed and technologically enriched, museum kits can bridge linguistic, cognitive, and cultural gaps, offering a promising avenue for inclusive, multimodal, and culturally responsive education. Building on the museum kit's capacity for experiential learning, the integration of AR further expands its potential, offering immersive cultural experiences that support diverse learners.

2.4. Augmented Reality and Cultural Learning: A New Pedagogical Frontier

AR is redefining the landscape of cultural education by offering immersive, interactive, and context-aware learning experiences. In museum and heritage settings, AR overlays digital content, such as 3D models, animations, audio guides, and interactive narratives, onto physical artifacts and spaces, transforming passive observation into active exploration (Hellwig, 2024). This technological affordance is

particularly valuable for bilingual students with atypical development, as it supports multimodal engagement, scaffolds comprehension, and fosters motivation through playful interaction.

By integrating visual, auditory, and tactile modalities, AR experiences promote accessibility and engagement for learners with diverse cognitive and sensory profiles, offering playful, personalized learning pathways to cultural understanding (Van Erven & Darányi, 2025). In cultural learning environments, AR enhances learners by enabling them to interact with historical narratives, solve location-based challenges, and engage in role-playing scenarios. For example, learners might follow a virtual guide through a historical town, uncover hidden clues, or reconstruct past events using AR overlays. Thus, a deeper understanding of cultural content is promoted by situating learning within authentic, spatially anchored contexts (Poulimenou et al., 2023).

AR also supports inclusive education by adapting to diverse learning preferences. Visual learners benefit from rich imagery and animations, auditory learners from narration and soundscapes, and kinesthetic learners from physical movement and interaction with the environment. Moreover, AR applications can be designed to accommodate different levels of language proficiency, offering bilingual or multilingual content, subtitles, and interactive glossaries, features that are especially beneficial for students with language processing difficulties (Geng & Yamada, 2025). The integration of AR into museum education aligns with contemporary pedagogical trends such as gamification and transmedia storytelling. Through game mechanics, such as points, rewards, and progress tracking, AR applications can sustain learner engagement and encourage exploration without the fear of failure (Plass, Homer, & Kinzer, 2015; Voulgari, Panagopoulos, & Garneli, 2024). Transmedia storytelling, on the other hand, allows cultural narratives to unfold across multiple platforms and formats, enabling learners to construct meaning through a variety of interconnected experiences. Importantly, AR fosters a sense of agency and discovery (Poulimenou et al., 2023).

Augmented Reality (AR) can support a shift from passive to more active, constructive, and even interactive forms of learning, aligning with the levels of cognitive engagement described in the ICAP framework In doing so, it enables learners to move beyond information reception and become active constructors of cultural knowledge. This is particularly empowering for atypically developing students, who may struggle with traditional instructional formats. By offering alternative pathways to knowledge, AR contributes to a more equitable and engaging educational experience (Kaimara, Deliyannis, & Oikonomou, 2022; Kaimara et al., 2021). In sum, AR represents a powerful pedagogical tool for cultural learning. When integrated into museum kits and educational programs, it enhances accessibility, supports bilingual language development, and cultivates a deeper connection to cultural heritage. Its

potential to transform informal learning environments into inclusive, interactive, and meaningful spaces makes it a cornerstone of 21st-century education.

Research shows that AR-based games, such as interactive scavenger hunts or guided historical tours, can foster problem-solving skills and support meaningful interactions with real-world environments. When combined with geolocation and contextual storytelling, AR becomes especially effective in engaging learners across diverse subject areas including history, archaeology, geography, linguistics, and the arts (Fokides, 2018; Voulgari et al., 2024).

Taken together, these strands of research and pedagogical approaches establish a strong foundation for designing educational tools that support bilingual language development and cultural engagement. Building upon this pedagogical foundation, the following sections illustrate the practical implementation of these principles through the "DisCot" application in Corfu Old Town. Unlike traditional museum kits, "DisCot" integrates gamification and transmedia storytelling within a real-world cultural environment, providing an unprecedented level of inclusivity and interactivity. This innovative approach creates immersive learning experiences tailored to diverse learners, especially atypical bilingual students, enhancing both language acquisition and cultural awareness. The implementation of these principles is exemplified in the case study that follows.

3. THE "DISCOVER CORFU OLD TOWN" (DisCot) APPLICATION

The Old Town of Corfu, a UNESCO World Heritage Site since 2007 and a protected historical monument since 1980, represents a unique cultural landscape that blends Byzantine, Venetian, neoclassical, and modern elements into a vibrant urban mosaic (Poulimenou et al., 2023). With its narrow alleys (kantounia), fortresses, churches, mansions, and public spaces, the town functions as a "living museum," where history, architecture, and everyday life coexist harmoniously. This dynamic environment offers rich opportunities for experiential learning, particularly in the context of cultural heritage education.

Within this context, the "Discover Corfu Old Town" (DisCot) application was developed as a gamified, transmedia educational tool. Designed within the framework of the "Hologrammatic Corfu" project, funded by the European Union, DisCot was conceived to enhance accessibility and engagement with Corfu's cultural heritage through innovative digital means (Poulimenou et al., 2023). Although not part of the initial project deliverables, the idea for this application emerged from the wealth of multimedia content and accessibility data generated during the project's implementation. DisCot integrates AR, gamification, and transmedia storytelling to create

an inclusive, interactive learning experience. It guides users through more than 12 points of interest, each selected based on historical significance and physical accessibility, thus ensuring that learners with mobility challenges can fully participate. This approach aligns with the principles of UDL (CAST, 2018).

The educational design of DisCot draws heavily on the pedagogical principles discussed earlier. Through AR, users interact with digital overlays presenting historical facts, narratives, and challenges. Gamification features, such as missions, rewards, and progress tracking, motivate learners to engage deeply with the content. Transmedia storytelling enables the narrative to unfold across multiple formats, including maps, flashcards, and audio guides, enriching the learning journey. Crucially, DisCot supports bilingual and atypically developing learners by offering multimodal content and differentiated interaction pathways. Visual, auditory, and kinesthetic elements are combined to cater to diverse learning styles, while the narrative structure promotes language development through contextualized and meaningful use. The design also embraces inclusive pedagogical values, ensuring no learner is excluded due to physical or cognitive barriers.

The application was designed to achieve the following educational objectives:

- Promote bilingual vocabulary acquisition and syntax development through contextualized use.
- Foster cultural awareness and historical knowledge of Corfu Old Town.
- Support inclusive participation of atypically developing learners through multisensory, differentiated learning.
- Encourage collaboration and peer learning in real-world, situated contexts.

In summary, DisCot exemplifies how digital innovation, cultural heritage, and inclusive pedagogy can converge to create transformative educational experiences. By leveraging AR and gamification within a real-world cultural setting, the application enhances engagement while promoting accessibility, cultural understanding, and bilingual language development, particularly for learners who benefit from alternative, multisensory educational approaches. The following section details the design structure and development of the "DisCot" application and its museum kit.

3.1. The Conceptual Framework of the DisCot Application - The Museum Kit

In essence, the application is an AR location-based treasure hunt. It is organized around twelve historically and culturally significant landmarks within Corfu old town, each serving as a station in the narrative journey. The experience is designed to be inclusive, multisensory, and adaptable to a variety of learning needs and pref-

erences. The application and its associated museum kit consist of both a traditional physical game, comprising envelopes, flashcards, and AR markers for individual stations, and a fully digital version (see Figure 1).

Figure 1. DisCot kit

The digital version enriches user engagement through audio narration, AR storytelling, and an integrated digital game that follows transmedia principles. Additional features for team leaders include subtitle activation and the display of a virtual letter or a digital map at the game's conclusion. Prior to the use of the application, educators discreetly coordinate all necessary technical arrangements with participants' families. The application can be pre-installed on participants'

mobile devices, while its various parts are progressively revealed during play. This design enhances the element of surprise and strengthens the immersive quality of the transmedia narrative.

The treasure hunt begins either at the hotel where students and teachers are staying (during a school excursion) or at a designated meeting point in Spianada square, such as "Palko" (Station 0), a symbolic cultural site in Corfu. The team leader, typically a teacher, receives a kit that includes:

- Game instructions
- A set of envelopes (60 envelopes for the full 12-station game or 30 envelopes for a shortened 6-station version)
- A compass
- A traditional map of Corfu old town.

Each envelope is clearly labeled with the station number (e.g., 1, 2, 3) and a sub-task identifier, for example "1.1" or "1.2" referring to the first and second tasks of Station 1, respectively. At the start, students receive the first envelope containing a brief historical introduction and an initial task, such as "Find the temple's façade." Using this clue, students locate the specific landmark. The game follows a structured sequence of envelopes per station (Table 1):

Table 1. Content Overview of Envelopes in the "DisCot" AR Educational Game

Envelope	Content description
1	Historical information and a prompt to identify a site feature
2	A photo to scan with a mobile device, triggering an AR video
3	Multiple-choice quiz based on the video; correct answers earn a letter and positive feedback (✓), while incorrect answers trigger a red (X)and buzzer
4	The letter earned at that station
5	A clue guiding players to the next station

There are two difficulty levels:

- Level 1: Full 12 stations
- Level 2: Shortened 6 stations, skipping from station 5 directly to station 12

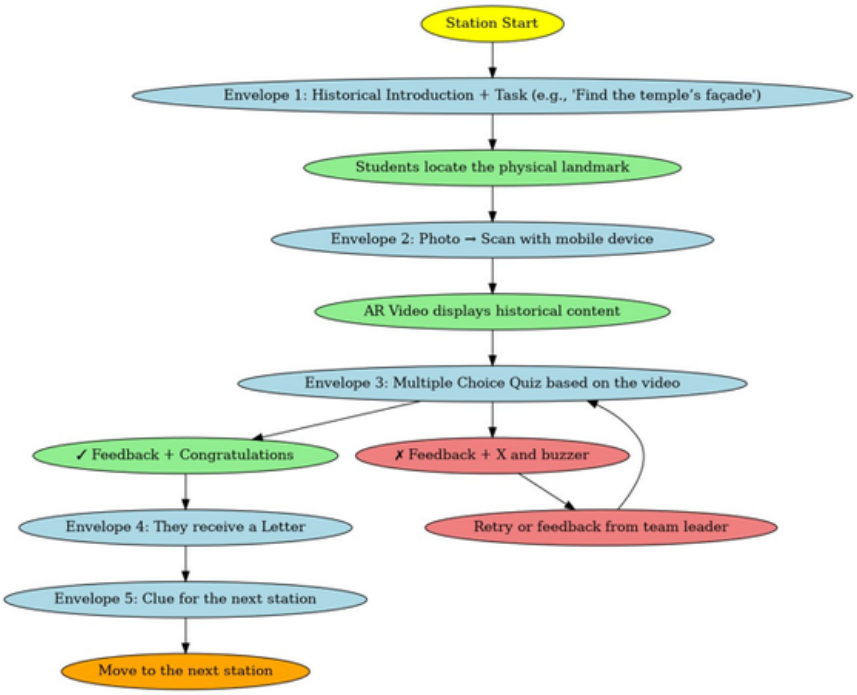
The 12 stations version includes the following:

1. Old town's fortresses (St. George church)
2. Statue of Schulenburg

3. Palace of St. Michael and St. George
4. Liston
5. Saint Spyridon church
6. Well mouth in Kremasti square (Campo Veneziano)
7. The Metropolitan church of Our Lady Spilaiotissa, St. Vlasios and St. Theodora Augusta
8. Gate of the new fortress
9. Jewish synagogue "Sinagoga Vecchia"
10. Annunziata Bell tower
11. "Duomo" cathedral of Saints James and Christopher
12. Town hall (Loggia Nobilei-The Nobles Arcade)

The game starts with Envelope 0, which includes the introductory narrative and instructions directing players to the Old Fortress (Station 1). At each station, players follow the structured sequence described above. Figure 2 details the decision flow of player actions and feedback during AR activities. At the final station, players arrange the collected letters to reveal the phrase "ΝΗΣΟΣ ΦΑΙΑΚΩΝ" ("Island of the Phaeacians"). Multiple teams can participate simultaneously, with the first team to solve the phrase declared the winner. Navigation is supported by clues, a compass, coordinates, or by engaging with locals.

Figure 2. The activity flow



Envelope 1:	Provides historical information and a question prompting players to identify a specific feature of the site
Envelope 2:	Contains a photograph of the feature. Players scan it to trigger an AR video
Envelope 3:	Includes a multiple-choice question based on the video. A correct answer earns a letter and positive feedback (✓), while an incorrect answer triggers a red X and a buzzer sound
Envelope 4:	Contains the letter earned for that station.
Envelope 5:	Provides the clue to the next station

To better illustrate the gameplay, below is an example of how the first three stations unfold during a typical game session.

- Station 0. Hotel or Spianada square. Team leader: *"Good morning, everyone! Are you ready for an adventure in Corfu? Today we'll explore the city and uncover hidden treasures. Let's begin by scanning this QR code."* Players scan the QR code and receive instructions leading them to the Old Fortress (see Figure 3).

Figure 3. Old town's fortresses (St. George church)

- **Station 1. Old fortress (entrance**). Team leader: *"We've arrived at the Old Fortress, the largest medieval monument in Corfu. Let's open the first envelope."*

Envelope 1.1. Prompt: "The Old fortress dominates a rocky peninsula with two peaks. It was built during the early Byzantine period (6th century). Find the neoclassical façade of St. George's church." Players locate the church façade. Team leader: *"Well done! Let's open the second envelope."*

Envelope 1.2. Photo of the façade. "Scan the photo to watch the video." Players scan and watch the AR video.

Envelope 1.3 (the multiple-choice question): "What is the architectural style of the church?"

1. Byzantine
2. Georgian
3. Gothic

Team leader: *"Correct! You've earned the letter N. Great job! Let's open the next envelope."*

Envelope 1.4: Letter "N"

Envelope 1.5: "To find the next station, look for the statue of a German military figure near the fortress entrance, overlooking the sea."

Figure 4. Schulenburg statue

- **Station 2: Schulenburg statue** (see Figure 4). Team leader: *"We've arrived at the Schulenburg Statue. Let's open the first envelope."*

Envelope 2.1: Prompt: "This statue of a German military officer was sculpted in 1718. Find the statue." Players locate the statue. Team Leader: *"Well done! Let's open the second envelope."*

Envelope 2.2: Photo of the statue. "Scan the photo to watch the video." Players scan and watch the AR video.

Envelope 2.3 (the multiple-choice question): "What is the historical significance of the Schulenburg statue?"

1. It honors Schulenburg's role in defending Corfu during the 1716 Ottoman siege.
2. It symbolizes Venetian rule in the 18th century.
3. It commemorates the Venetian victory over the French.

Team leader: *"Correct! You've earned the letter H. Great job! Let's open the next envelope."*

Envelope 2.4: Letter "H"

Envelope 2.5: "To find the next station, look for a grand neoclassical building with two gates: the Gate of St. Michael and the Gate of St. George."

Figure 5. Palace of St. Michael and St. George

- **Station 3: Palace of St. Michael and St. George** (see Figure 5). Team leader: *"We've arrived at the Palace of St. Michael and St. George. Let's open the first envelope."*

Envelope 3.1: Prompt: "This neoclassical palace was built between 1818 and 1823. Find the entrance to the Museum of Asian Art." Players locate the museum entrance. Team leader: *"Well done! Let's open the second envelope."*

Envelope 3.2: Photo of the entrance. "Scan the photo to watch the video." Players scan and watch the AR video.

Envelope 3.3: "What material is used to clad the building?"

1. Carrara marble
2. Maltese limestone

3. Granite

Team leader: *"Correct! You've earned the letter Σ. Great job! Let's open the next envelope."*

Envelope 3.4: Letter "Σ"

Envelope 3.5: "To find the next station, look for a cluster of buildings at the western edge of Spianada square."

This pattern repeats until the final puzzle is solved.

3.2. Pedagogical Design and Development of the DisCot Application

In line with these pedagogical trends, the interactive structure of the DisCot application reflects a modular, learner-centered design informed by inclusive, discovery-based pedagogies (Bruner, 1961). Each point of interest (POI) functions as a self-contained learning unit, aligning with constructivist approaches that emphasize active exploration and contextual learning. The sequence of interactions is designed to support cognitive engagement while accommodating the diverse needs of atypically developing bilingual learners, in accordance with principles of Universal Design for Learning (CAST, 2018; Freeman-Green et al., 2023) and translanguaging-based inclusive practices (García & Lin, 2016). Overall, the application integrates game-based learning strategies and narrative techniques to enhance learner engagement and cultural immersion. The experience is structured around mechanics that reward progression and foster active discovery. As the learners complete tasks at each station, they earn letters that contribute to solving a final riddle word. Physical artifacts, such as envelopes, flashcards, and maps, are complemented by digital tools, including AR-triggered videos and interactive quizzes. This transmedia structure enables learners to engage through diverse modalities, supporting motivation and retention through incremental, narrative-driven learning. As already mentioned, the primary goal of DisCot is to immerse learners in a structured game environment enhanced with AR elements, multimedia prompts, and playful challenges. This approach not only motivates exploration and interaction but also deepens cultural awareness through multisensory engagement. Importantly, the experience is designed to unfold under the guidance of a teacher, who plays a key role in facilitating the activity. Acting as both narrator and educational guide, the teacher scaffolds the experience while also taking on technical and pedagogical responsibilities. These include managing the game flow, supporting students with the app, delivering historical context, and adapting content to the group's needs. While this multifaceted role can be demanding, literature highlights the importance of institutional and pedagogical support for teachers using AR (Kaimara, 2023;

Kaimara, Fokides, et al., 2021, 2022). The development of the application followed a human-centered design methodology informed by inclusive pedagogy, transmedia storytelling, and mobile AR that is appropriate for experiences in the physical environment. The implementation focused on offering an engaging, multisensory experience tailored to bilingual learners with diverse educational needs. This section outlines the technological tools, interaction design and inclusive game mechanics, and development stages, that underpin the final application.

3.2.1. Technological Tools

The application was developed using open-source and browser-based technologies to maximize accessibility and portability. The main development tools, HTML5, CSS3, and JavaScript were used for the structural layout, content styling, responsiveness of the user interface, as well as for implementing game logic, UI interactivity, and state transitions. p5.js (https://p5js.org/), a JavaScript library, was also used for creative coding and visual effects, transitions, and interactive animations. Additionally, MindAR.js (https://www.mindar.org/), an open-source tool that can be used for building image-tracking types of AR applications, allowed the implementation of image-based AR triggers (photos of the game's POIs) to activate interactive content, such as videos. Photographs of the 12 POIs were taken and processed to be used as markers. The twelve markers were printed to be available in the physical environment, and at the same time, they were compiled into the appropriate format to be used as the targets of the application that combines the marker with the digital content. Figure 6 illustrates the initialization of the Augmented Reality (AR) session using the MindAR.js library. The code connects predefined image targets with the web-based environment, enabling the recognition of physical markers and the overlay of digital content during the user's interaction with the application.

Figure 6. MindAR.js Code Snippet for AR Setup

```
onst mindarThree = new window.MINDAR.IMAGE.MindARThree({
  container: document.body,
  imageTargetSrc: './assets/targets.mind',
});

const { renderer, scene, camera } = mindarThree;
await mindarThree.start();
renderer.setAnimationLoop(() => {
  renderer.render(scene, camera);
});
```

This material was uploaded to GitHub to be available for any user who wants to run the experience. Finally, videos were taken and enriched with the educational content, using voice and subtitles, ensuring accessibility for hearing-impaired users and strongly supporting the bilingual students as they will have the opportunity to read additionally to hearing the content (Table 2).

Table 2. Technologies used in DisCot implementation

Tool/Library	Function
HTML5/CSS3/JS	Layout, styling, logic, responsiveness
p5.js	Creative coding for animations and interactions
MindAR.js	Marker-based AR integration
GitHub & GitHub Pages	Hosting, collaboration, open-source distribution
DaVinci Resolve / Clideo.com	Video editing, subtitles, compression

The design prioritized low hardware requirements and cross-device compatibility, making it suitable for use on standard Android and iOS devices with a modern browser. Finally, the code is uploaded on GitHub (https://github.com/) and openly accessible to the public through a GitHub Page, allowing educators, developers, and researchers to explore, adapt, or extend the application for their own use cases. By adopting an open-source model, the project fosters transparency, collaboration, and long-term sustainability. It also encourages community-driven improvements and localization efforts, making the application scalable across different languages, cultural contexts, and educational settings (McDonald & Goggins, 2013).

3.2.2. Interaction Design and Inclusive Game Mechanics

The experience begins with a welcoming start screen that prompts learners to select between two levels of difficulty, inspired by the treasure hunt context of the AR game (see Figure 7). The JuniorHunt mode presents a shorter trajectory through six selected POIs, ideal for younger users or those requiring less cognitively demanding tasks. Conversely, the MasterHunt mode offers a more comprehensive exploration of twelve POIs. This branching pathway structure allows educators to differentiate the experience according to group dynamics, time constraints, or individual learning profiles (Kaimara, Deliyannis, et al., 2022). To ensure intentional participation, the “Start” function is only activated after the learner has made a conscious choice regarding the game mode.

Figure 7. Welcome screen of the DisCot

Upon entering the main interface, learners are presented with a digital map highlighting the locations that correspond to their selected route. The map is accompanied by a visual progress tracker: a series of blank letter slots that gradually reveal the solution to a cultural riddle embedded in the game narrative. Each completed station contributes one or two letters, depending on the selected difficulty level, toward the construction of a meaningful final phrase (see Figure 8 & Figure 9).

Figure 8. The digital map with the 12 POIs and the visual tracker

Figure 9. The visual tracker after the correct answer to the first question

This puzzle mechanism promotes sustained engagement through incremental reward and narrative closure, while also encouraging cooperative play in team-based scenarios (Fontes et al., 2024). Interactivity at each station begins with an AR scanning action, which is activated upon pointing the mobile device at a specific photographic marker included in the physical museum kit or maybe found on-site. This action triggers an augmented video experience, offering historical and cultural insights through subtitled narration. Subtitles are presented, enabling bilingual learners to process content through both auditory and visual channels (see Figure 10).

Figure 10. The screen that plays the video of the first POI

Once the video concludes, learners are directed to a quiz interface. Here, a multiple-choice question reinforces comprehension and encourages retrieval practice. Learners are allowed to attempt the question multiple times without penalty, fostering a growth mindset and reducing test anxiety (see Figure 11).

Figure 11. The multiple-choice question that players need to answer by selecting the right answer

The design of the quiz emphasizes immediate feedback: correct answers are met with audio-visual affirmations and progression prompts, while incorrect responses generate error signals that prompt reflective re-engagement with the material in a constructive trial and error process (Chorianopoulos et al., 2014). Upon successful completion of the quiz, learners are returned to the main interface, where their progress is visually updated. The map indicates the station as completed, and the appropriate letters are revealed in the final puzzle space. This cyclical structure of exploration, interaction, and reward ensures a seamless progression through the narrative journey while promoting spatial memory, narrative coherence, and linguistic activation in real-world contexts.

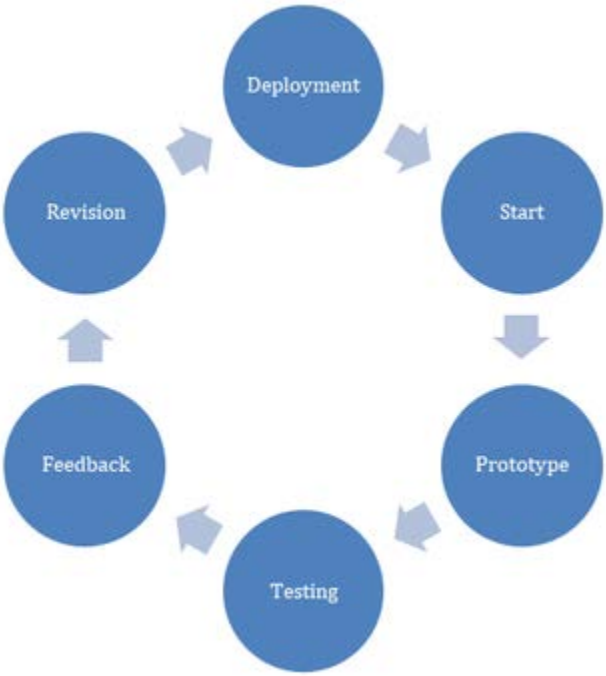
Navigation and access are further enhanced by a persistent top-level menu, which provides learners with direct access to the AR scanner, the choice to continue to the quiz, and an option to return to the starting screen. The hybrid use of physical materials (e.g., envelopes, maps, markers) and digital tools (e.g., AR, video, and quizzes) creates a multisensory ecosystem that is both engaging and pedagogically robust. Overall, the interaction design of DisCot exemplifies a learner-centered, inclusive approach that merges storytelling, place-based learning, and mobile AR technology. It transforms Corfu's old town into a distributed learning environment, where the boundaries between formal and informal learning blur, and where language development becomes a lived, embodied experience mediated by space, narrative, and play.

In parallel, the application is grounded in accessibility and inclusivity principles that ensure equitable participation for all users. Subtitled videos accompany

all audiovisual content, providing vital support for hearing-impaired learners and reinforcing comprehension for bilingual users. To reduce anxiety and encourage persistence, the quiz system permits unlimited attempts. The interface design emphasizes clarity and simplicity, using high-contrast visuals and intuitive icons to assist learners with attention or visual difficulties. Multimodal delivery, integrating text, audio, and AR, caters to diverse sensory and cognitive profiles, aligning with Universal Design for Learning (CAST, 2018). Together, these features create an inclusive and responsive learning environment that supports meaningful engagement across a wide range of learner needs.

Key phases of development included prototyping, testing, iterative refinement, and final deployment. Each phase was informed by feedback from educators and learners, ensuring that the application remained accessible, pedagogically sound, and contextually relevant (see Figure 12).

Figure 12. Iterative Development Cycle Diagram



4. LIMITATIONS AND FUTURE WORK

Despite its innovative and inclusive design, the DisCot application has several limitations. First, while the application is accessible through standard mobile browsers, performance may vary depending on device specifications and internet connectivity, particularly in outdoor or heritage areas with weak signals. Second, while subtitles and multimodal content support diverse learners, additional layers of personalization, such as audio speed control or text simplification, could further enhance accessibility for users with specific learning disabilities or younger learners. Third, the application relies heavily on teacher facilitation and thus requires educators to be adequately trained and technologically confident to guide learners effectively through the experience. To address these limitations and further enhance the application's educational potential, future work will focus on expanding its functionality and reach. Planned developments include the integration of GPS-based triggers to support fully location-aware navigation, multilingual voice narration for broader language support, and the development of an offline mode to ensure usability in low-connectivity environments. Additional customization features, such as user profiles and adaptive difficulty levels, are also under consideration. Another important direction for future development is the creation of a fully hybrid version of the application, by designing the game also as a traditional board game that can be played either in parallel with or as an alternative to the digital version, thus fully embodying the philosophy of transmedia learning. Finally, future research will include a comprehensive evaluation of learning outcomes and user engagement across different educational contexts and learner profiles, contributing to a broader understanding of AR's role in inclusive bilingual education.

5. CONCLUSION

The DisCot application's development reflects an intentional synthesis of inclusive pedagogy, location-based learning, and transmedia storytelling. By combining low-barrier technologies with AR-enhanced museum practices, DisCot enables atypically developing bilingual students to engage meaningfully with both language and culture. Its flexible, playful design ensures that all students, regardless of ability, can participate in a rich, multisensory journey through the cultural heritage of Corfu old town. As a result, DisCot not only supports bilingual vocabulary acquisition and cultural literacy but also models a sustainable, inclusive approach to digital heritage education, offering a replicable framework for other historical contexts.

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