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Designing game-driven augmented-reality scenarios with real-world implications to facilitate intercultural exchange: the alien scenario

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Abstract: Building on Klopfer and Squire's (2008) study on design-based research (DBR), this paper investigates the process involved in conceptualising, designing, developing, and implementing augmented reality (AR) scenarios during intercultural exchanges, which were enacted as part of a transnational interdisciplinary project, ReDesign. In the case study discussed, the potential of involving all interested stakeholders in the design process of the AR scenario and the subsequent two scenarios are explored. In addition, during the testing phase, an adept Dutch teacher trainer and five instructors contribute to the enhancement of the AR scenarios, through their feedback suggestions. An alien scenario is initially designed, while students are invited to share salient cultural artefacts which are then designed in 2D or 3D. Three scenarios are designed that have broader socio-political, institutional, and pedagogical implications, while enacting affordances to reflect on students' culture and experience the pedagogical potential of novel technologies implemented in their curriculum.

Keywords: augmented reality; design-based research; DBR; affordances; intercultural exchange.

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Biographical notes: Stella Hadjistassou is a Research Fellow at the KIOS Research and Innovation Center of Excellence at the University of Cyprus, where she conducts research on the role of XR technologies in second/foreign language learning, teacher training, and engineering education. She has extensive teaching experience both in the USA and Cyprus. She has coordinated and/or participated in multiple large-scale EU-funded projects, including ARIDLL, DIMPE, DiMPAH, ReDesign, TRANSIT, and ReCharge.

Petros Louca is an A' Class IT Officer managing the Sector of Applications Development of Information Applications Service at the University of Cyprus. He also collaborates with researchers at the KIOS Research and Innovation Center of Excellence on EU projects, including ARIDLL, DIMPE, DiMPAH, and ReDesign. Among his IT multi-disciplinary work involvement, he focuses on designing, developing and deploying augmented reality mobile applications for educational purposes, based on the indicated curricula. The aim is to achieve a higher degree of student engagement by employing immersive learning experiences.

1 Introduction

Reeves and Lin (2020) propose a paradigm shift in educational technology research by making an explicit call to all interested stakeholders to steer research away from *specific tools or technological innovations* to undertake a more comprehensive pedagogically-driven research approach that is embedded both within the local and global challenges. As Reeves and Reeves (2015) postulate, "most of research agendas focus on things (e.g., tablet computers) rather than problems (e.g., the lack of readiness for higher education endemic among high school graduates)" (p.29). A comprehensive pedagogical framework, however, calls for shifting attention away from models where teachers and students are perceived as end users of these tools to a model where users are actively involved and contribute to the design and development process. In second and foreign language pedagogy, even the most technologically adept teachers, who can leverage a wide range of novel tools and applications to enact innovative and immersive learning experiences, often neither participate nor contribute to the design of cutting-edge tools and applications. Instead, as end users of technology, they often strive to become acquainted with the different tools and applications and evaluate their potential in an *ad hoc manner* to enrich students' learning experiences and address learning and teaching challenges (see Kessler, 2006; Compton, 2009). However, meaningful teaching and learning challenges experienced in the actual teaching contexts should form the catalyst for designing, developing, and deploying new tools and applications that can enact affordances for learning and competence and skills development. Technology design and development should be galvanised by pedagogically potent agendas that have a broader societal, educational, and learning impact and implications. Pedagogy, research, and technology are intertwined and form part of a broader ecology that can ignite change, innovation, learning, skill development, and social inclusion. Consequently, the development and deployment of tools and applications should be enacted on the broader research, pedagogical, and methodological trajectories that can offer an added value to the culturally-driven teaching and learning practices (DelliCarpini, 2012; Arnold and Ducate, 2015).

In this process, second and foreign language teachers' involvement and collaboration with interdisciplinary teams is a social and pedagogical imperative. Vibrant cross-sectional, interdisciplinary collaborations among teams including instructional designers, software developers, second/foreign language researchers, instructors, and students should form an indispensable component of the iterative processes involved in designing, developing, and deploying tools and applications that are ingrained in concrete pedagogical values and goals. At the same time, key societal challenges that exert a powerful impact on both the teaching and learning practices can be tackled through the design and development of novel technologies. As Carr et al. (2018) correctly note, "Real world problems rarely regard disciplinary boundaries" (p.35) (see also Carayol and Nguyen Thi, 2005; Klein, 1990). Real-life problems such as the imparities between labour market needs and college-level education or immigrants confronted by cultural and linguistic barriers in their pursuit of social, political, and financial security could be integrated into the curricula. Different tools and applications could be designed and deployed in the curricula across academic institutions to address such critical sociopolitical and institutional challenges and guide in understanding the pedagogical role of such tools in promoting learning and collaboration during intercultural exchange. Their design could be enacted within the underlying principles of design-based research

(DBR) which provides the mechanisms for capturing both the theoretical and practical trajectories of the iterative processes involved in development and implementation of novel technologies in learning and intercultural exchange.

2 Design-based research

DBR is situated within the trajectories of pragmatic inquiry and strives to identify the local impact of research as exemplified through the lens of specific theoretical trajectories. As Kennedy-Clark (2013) indicates, DBR aims "to develop and refine the design of artefacts, tools and curriculum and to advance existing theory or develop new theories that can support and lead to a deepened understanding of learning" (p.26). In a similar vein, Barab (2014) argues that "the goal of DBR (sometimes also referred to as design experiments) is to use the close study of learning as it unfolds within a naturalistic context that contains theoretically inspired innovations, usually that have passed through multiple iterations, to then develop new theories, artefacts, and practices that can be generalized to other schools and classrooms" (p.151). Effective interventions can potentially contribute to constructive impact on learning and guide the methodological implementations and further advancement of theoretical paths. DBR is not situated within the broader framework of research methodologies that make inferences or generate empirically grounded outcomes. It is rather ingrained in the locally situated contexts and rich interpretations of the pragmatic contexts in which it unfolds. At the same time, it offers a path to link research to theoretical explanations. Wang and Hannafin (2005) conclude that DBR includes five defining characteristics: "(a) pragmatic; (b) grounded; (c) interactive, iterative and flexible; (d) integrative; and (e) contextual" (p.7). Collins et al. (2004) assert that DBR delves into critical elements related to learning including the calls for:

1 theoretical inquiries and understandings into learning in pragmatically-oriented contexts

2 investigation of the learning processes in actual contexts

3 focus placement on the restricted learning variables that we investigate through research

4 generation of research outcomes from formative evaluation.

In Cobb et al. (2003), the DBR "entail both 'engineering' particular forms of learning and systematically studying those forms of learning within the context defined by the means of supporting them" (p.9). Iterations form an integrative part of this process. In their study on a platform that affords augmented reality (AR) games, Klopfer and Squire (2008) describe DBR in a six-phase process: "brainstorming, design, development, field trials, classroom implementations, and platform designs" (p.209). Klopfer and Squire (2008) developed an educational software that aims to facilitate the development of investigative skills, such as data collection, as players are confronted with a community struggling to overcome various health problems and strive to identify their causes. Similarly, Barab et al. (2010) examine two cases of transformational play and personal engagement in a multiuser virtual learning environment, Quest Atlantis. In the first case, students take the role of environmental scientists investigating the dwindling fish

population and propose potential solutions. In the second case, students are immersed in Modern Prometheus where they are placed in a plague-wracked town and collaborate with writers to develop a cogent argument supporting or challenging Doctor Frank's experiment. Bodzin (2011) examines the underlying role of a geospatial information technology (GIT)-driven curriculum in enhancing students' understanding on areas related to land use and in guiding them improve their spatial thinking skills. Bodzin (2011) concludes that the study provides "support that spatial thinking can be learned, can be taught formally to all students in an urban middle school, and can be supported by appropriately designed curriculum and geospatial information technologies" (pp.295–296).

Anderson and Shattuck (2012) demonstrate that "science is the discipline most studied in DBR and K-12 the age group in our top cited articles" (p.20). Some studies have been conducted in pre-service teacher preparation and digital literacy. For instance, Angeli and Valanides (2009) proposed technology mapping (TP) as a groundwork for developing a better understanding and implementing a constructivist framework that can promote the construction of technological pedagogical content knowledge (TPCK). Angeli and Valanides (2009) concluded that the design of technology mediated experiences is embedded in context-driven variables such as teachers' epistemological beliefs, experiences, and expectations on instructional practices, as well as institutional practices and goals. Further studies in this area could contribute to the implementation of design research principles to enhance learning goals and activities mediated by novel technologies such as AR and examine all stakeholders' contribution to this process. If education is intended to serve the needs of a wide and diverse student population, then it needs to address this imperative. Without technology integration into the curricula, we simply fail to equip students with the pivotal skills to break into the professional market and achieve social inclusion, employability, and professional advancement. If students and teachers are anticipated to integrate technology into their teaching and learning, they should also be actively engaged, contribute, and participate in the design of culturally-driven learning environments, applications, and/or tools (see Kirschner, 2015; Könings et al., 2011). Teachers and students could use their imagination, cultural, and linguistic knowledge to contribute to this process, which should not be restricted to software development.

3 The implementation of AR in educational contexts

Multiple AR software and hardware have been designed and implemented to blend users' physical surrounding with virtual artefacts and settings and superimpose information that can promote a better understanding of complex constructs, reduce cognitive load, maintain users' attention, and enhance engagement level, interaction, and learning. AR has the capacity to augment users' perception, cognition, and emotion, as well as to guide users in participating in different interactions and undertaking specific actions. Azuma et al. (2001) postulated that AR interacts with the physical and virtual environment and aligns virtual and real artefacts. AR has received considerable attention in education – especially in STEM-related subjects where the potential of harnessing AR applications has been explored as a path to enhance spatial capacity and develop conceptual understanding of complex scientific constructs, statistical reasoning, and scientific inquiry (see Conley et al., 2020; Cheng and Tsai, 2013; Dunleavy et al., 2009). Ibáñez

and Delgado-Kloos (2018) conclude that, in education, AR is popular in two central modes: "The first is image- or marker-based AR, which requires recognition of a marker or specific object to bring up digital information; the second is location-based AR, which makes use of a device's GPS to identify locations at which computer-generated information should be superimposed" (p.110).

Researchers and educators have focused on the pedagogical implications emerging from the implementation of AR applications in different subjects and areas of study. Customisable artefacts demonstrating and facilitating interaction with abstract scientific concepts and structures, as well as different environments, have been developed and deployed to explore their role in improving learners' spatial understanding, formulation of concept maps of scientific constructs and visualisation and understanding of abstract phenomena (see Rutten et al., 2011). Sotiriou and Bogner (2008) leverage AR to examine its role in promoting learning as students participate in various activities to build scientific representations of scientific concepts. Sotiriou and Bogner (2008) demonstrate that AR-mediated visualisations can contribute to overcoming common misconceptions about friction, while students also exhibit higher level of interest and enjoyment than the comparison group. Using DBR, Dunleavy et al. (2009) explore how teachers and students implement AR as a mechanism to facilitate or hinder learning. Dunleavy et al. (2009) illustrate that both teachers and students note that joint problem-solving activities mediated by AR can be highly engaging, particularly "among students who had previously presented behavioral and academic challenges for the teacher" (p.7). In a more recent study, Conley et al. (2020) deployed AR to promote the development of statistical reasoning skills in college students and view on perception and collaboration. Conley et al. (2020) indicate that AR can be particularly beneficial "for students without prior knowledge of statistical reasoning" and can enhance their perception of engagement (p.1).

Bacca et al. (2014) demonstrate that, even though AR has been primarily deployed in science-related subjects, 40.6%, some attention has also been paid to the 'arts and humanities', with 21.9% of the studies focusing in various related areas, including language learning. The interactive mode of AR technologies can potentially immerse learners in novel, authentic culturally-driven learning experiences that expand beyond the trajectories of institutionally embedded learning experiences. As Kessler (2018) argues, "By layering digital content upon the physical world, we can enable students to interact with one another within any space as if they were in a target language culture environment and thus engage with one another in a familiar space in wholly new and varied ways" (pp.211–212). Immersing learners in the target culture environment through the deployment of AR has formed the subject of many studies, including Holden and Sykes (2011) who relied on the ARIS software to develop *Mentira* to "solve the prohibition-era murder of Dionisio Silve in order to clear their family's name and absolve the family of any guilt" (p.6). Using place-based AR, Hellermann et al. (2017) investigate "how public interactional practices for out-loud reading by small groups of English language learners facilitate the routinisation of interactional practices" (p.99). Hellermann et al. (2017) demonstrate that the re-textualisation processes can contribute to the development of interactional practices as students participate in the realisation of five tasks. In French, Perry (2015) introduces a location-based AR application, *Explorez* where students engage in a quest interact with artefacts, virtual characters, and media while participating in a virtual francophone setting. Perry (2015) demonstrates that "students engaged in meaningful activities during their interaction with the learning-tool

and that through the use of Explorez they ascertained real-world applications for their FL2 learning" (p.2314). These studies have demonstrated the potential of AR in enriching students' learning experiences through investigation-driven experiences, interactions, and exploration of different communities, task-driven activities, and imaginary explorations.

Driven by a DBR framework (Klopfer and Squire, 2008; Barab and Squire, 2004), the study outlines a bottom-up approach where an interdisciplinary pool of instructors, researchers, instructional technologists, and software developers collaboratively design and implement AR scenarios to expand the frontiers of intercultural exchange and learning. The goal is first to explore the potential of involving all stakeholders in designing AR scenarios that can enact affordances for learning, collaboration, cultural understanding, and enhancement of digital skills. The study draws on an interdisciplinary, transnational European funded project, ReDesign which aimed at promoting the internationalisation and digitalisation of curricula across academic institutions in Europe, through the development and implementation of specifically tailored tools, as well as the construction and enhancement of students' digital skills. In this paper, particular emphasis is placed on steering away from pervasive models where second and foreign language teachers are positioned as consumers of technology to examine instructors' contribution to the design and development of novel tools or what Ertmer and Ottenbreit-Leftwich (2010) term as "agents of change" (p.255). Second, the role of integrating newly designed scenarios into the curricula across academic institutions to promote intercultural exchange, learning, and collaboration is explored. Research on intercultural exchange has focused on various tools, including emails, communication tools, blogs, virtual learning environments, and a wide multiplicity of other tools (see Thorne, 2003; Basharina, 2007; Zheng, 2012; Sadler and Dooly, 2016; O'Dowd and Lewis, 2016; Hadjistassou and Molka-Danielsen, 2016). However, there is still a dearth of studies on the design, development, and deployment of image-targeted AR applications and their integration into the curricula across academic institutions to promote intercultural exchange. Further, in most studies, student and teacher involvement in this design process is overlooked. This study is guided by the need to address this gap in the field by situating AR development and deployment in real-life contexts and encultured in collaborative design practices that can enhance learning and teaching.

4 Research questions

Informed by the iterative nature of AR scenario design, the study explores not only how AR is infused in specific contexts but also how students and teachers can contribute to this design process. Expanding on these principles, the study is guided by the following research questions:

1 What are some of the underlying processes involved in the design, development, and deployment of novel AR applications to promote intercultural exchange?

2 How can all interested stakeholders contribute to the design process?

3 How can AR scenarios generate critical reflections on culture, and how can these reflections guide in expanding further the AR scenarios?

5 Methodology

To develop an in-depth understanding of the iterative processes involved in this design and development process, a case study was adopted. As Duff (2013) notes, case studies may provide a detailed, explicated, and extended understanding by examining "concrete instances of a phenomenon of interest" through various theoretical lenses, epistemological frameworks, and methodological traditions, including DBR (p.1) (see also Levy, 2015). Through a case study lens, the paper examines teachers, students, researchers, an instructional designer, and a software developer's contribution to the development of scenarios, features, pedagogical requirements, and subsequent scenarios to enrich students' learning experiences across academic institutions. More precisely, through an ecological lens, the study investigates the iterative processes involved in enacting affordances and contradictions in the design and development of AR scenarios. Examining these collective contributions and situating them within culturally embedded contexts guides in capturing the multiple complex culturally enacted processes involved in this process. At the same time, it sheds some light on the role teachers and students can have in the design process. These collective processes can guide in:

1 aligning and connecting the complex design process and teaching practice and learning

2 optimising AR scenarios through a systematic approach in AR development of multiple scenarios instead of a single AR scenario

3 capturing, in a comprehensive framework, the collective contributions, socially situated nature and complexities involved in the development of AR scenarios.

That is, the study moves beyond the integration of novel technologies into teaching and learning to capture the complexity involved in the iterative design processes of these AR scenarios, as well as the emergent affordances and contradictions generated in this process.

To capture these emergent processes, from the design to the implementation stage, this case study builds further on Klopfer and Squire's (2008) work on the different phases involved in designing pedagogically-driven software. Klopfer and Squire's (2008) design framework forms a guiding principle in addressing and examining the complexity, multifaceted, and multiparty nature of the iterations required for the construction and realisation of this activity. The design activity guides in the collaborative prototyping, implementation, and development of subsequent scenarios. First, the participating instructors' initially proffered scenario draws on a key genre that most teachers are confronted with in everyday practice, migrant children. The genre can serve as a mechanism to enhance awareness on the immense challenges that migrant families face. Second, this sociopolitical genre is enacted through a game-like scenario, which merges reality with imagination, enriching learning and immersing students in novel interactive learning experiences. Third, the scenarios forms a stepping stone in promoting critical reflections on culture, language, and cultural artefacts. This step is achieved within the context of intercultural exchange among students in the United Kingdom and Cyprus. As Anderson and Shattuck (2012) note, "being situated in a real educational context provides a sense of validity to the research and ensures that the results can be used to assess, inform, and improve practice in at last this one (and likely) other contexts" (p.16).

6 Participants

The interdisciplinary transnational team included a diverse pool of participants from different EU member states. As demonstrated in Table 1, the team included two experienced instructors in applied linguistics and computer-assisted language learning in the UK and Cyprus, a female research assistant in computer assisted language learning from Cyprus, an Austrian instructional designer, and a Greek-Cypriot software developer. Twenty-two students, 13 from an academic institution in the UK and 9 students from an academic institution in Cyprus also participated in the intercultural exchange and contributed to the design of the AR scenarios. Neither the students nor the instructors had participated in or contributed to the design of AR scenarios prior to this study. In addition, during the testing phase, a highly experienced Dutch teacher trainer and five instructors in various disciplines were invited to test and offer feedback on the functionalities of the AR application.

Table 1 Team member demographics

Participant	*Gender*	*Country of residence/study*	*Area of specialisation*
• Two instructors	• Female	• UK • Cyprus	• Applied linguistics • Computer assisted language learning
• A researcher	• Female	• Cyprus	• Computer assisted language learning
• A software developer	• Male	• Cyprus	• Software development
• An instructional designer	• Female	• Austria	• Instructional design
• College students	• 12 Females • 1 Male • 7 Females • 2 Males	• UK • Cyprus	• Second year in applied modern languages • First year in primary education

7 Procedure

As part of a larger study, the design team collaborated with instructors to design and develop a series of AR scenarios to facilitate intercultural exchange among students. The focus shifted from the use of existing AR applications to developing game-like but pedagogically embedded scenarios that would expand the trajectories of intercultural collaboration and enrich students' learning experiences through interactive and engaging activities, scenarios, and tools. Further, activities were developed, entrenched in sociopolitical implications, to enrich students' learning experiences and promote intercultural collaboration among students. A series of written activities were also

discussed including students' identification of salient cultural artefacts that would then be designed in 3D or 2D contexts and be added to develop additional AR scenarios. This paper captures and describes the complex processes involved in the various processes, from the conceptualisation to the realisation of these scenarios, as well as teachers and students' contribution to this process.

7.1 Phase one: ideation

The cross-platform engine, Unity was deployed to design and develop AR activities. AR was selected because it did not form part of the curricula of the two academic institutions involved in this project and students had not previously explored AR in any of their courses. AR scenarios could enact affordances for interaction with novel technologies. Further, intercultural exchanges did not form standard practice in educational curricula. This process called for activities that could promote collaboration, engagement, critical thinking, reflection, and cultural understanding. Following Cuendet et al. (2013), the AR activities were intended to expand beyond "the individual, team and class planes" (p.559) to consider critical elements, such as the extended classroom, communities, and sociopolitical trajectories at hand, curricula, their potential adaptation to meet students' needs, flexibility in AR activities, constraints and contradictions, and content to drive learning (see Kerawalla et al., 2006). Local conditions and extended EU sociopolitical challenges that had an impact on the teaching practice and were aligned with the curricula were also considered. For instance, the relentless and fierce migration crisis bounding European member states had a broader sociopolitical impact, with schools often struggling to accommodate migrant children's learning needs, and families striving to be equipped with new linguistic and cultural knowledge. During an initial virtual meeting among the interdisciplinary pool of stakeholders, different genres were explored including migration. This interdisciplinary pool suggested the integration into the curricula of this contentious issue as a path to thought-provoking discussions on critical issues related to society, culture, language, and education. The influx of migrants unequivocally affects society, education, and the labour market, with migrants often struggling to build the required linguistic proficiency to communicate in the target language and assimilate with the local culture. Building on this genre, the humanitarian crisis and the potential of relating it to their future profession would be explored.

At the same time, leveraging the game-like elements, creativity, and imagination afforded by this real-time development platform, the goal was to create scenarios that were fictional and captured students' imagination but had real-world implications. The image target nature of the AR applications also compelled this interdisciplinary team to contemplate the technological affordances and constraints of the unity 3D engine. Customisable learning scenarios blending fiction with reality and real-world with virtual content required a solid understanding of the AR engine, students' learning needs, and institutional requirements. Engaging all stakeholders with this process would offer an added pedagogical value to the project and turn learning and teaching into more meaningful activities. Exchanging views on the requirements, expectations, curricula implementation, deadlines, and possible risks also provided a better picture of the requirements, design, development, testing, deployment, and evaluation phases.

7.2 Phase two: contemplating functional requirements and specifications

Contemplating both the features and functionalities, as well as the inherent system limitations, of the cross-platform engine Unity, the research team collaborated closely with the software developer and instructional designer involved in the project to discuss the requirements with all interested stakeholders. Particular emphasis was placed on the nature of the collaborative activities, the use of mobile devices, the smooth blending of the physical and virtual environments to provide an interactive system and the need to adopt a multidisciplinary design approach. The cross-platform Unity is widely used by the game and VR/AR industry and was selected mainly because of the system's strong capabilities including

- cost-effective nature in comparison to other game development software
- user-friendly processes in app development and their extension to other platforms
- user-friendly nature and targeted tools for AR designs afforded through its Vuforia AR software development kit extension and AR Foundation plug-in package
- effective rendering of high quality 2D and 3D images and scenes
- broad assets store/add-ons library and VR/AR hardware gear support
- solid and fast programming language, C#, to optimise game development and customisation.

Unity's rich repertoire of 3D objects and audio galleries would allow the research team to design and develop scenes, insert artefacts, scripts, and other light and physical effects. This step was crucial in eliminating the time-consuming process required by other-related software to develop and layout scenes. However, some functional limitations were also considered and steps were undertaken to overcome them, including exploring the potential of importing character prerecorded animations, such as Motion Capture data (MOCAPs) to generate the envisioned character behaviour. Autodesk Maya 3D and 3D Studio Max for 3D modelling object import, manipulation, and export to Unity, as well as LunaPic, were also explored, which were implemented for image resolution. TurboSquid's online assets library was also used. Upon collective discussion of these software and their capabilities, all interested stakeholders developed a better idea of the objectives of the AR activities, resources, and timelines.

7.3 Phase three: designing the AR scenario

The interdisciplinary team exchanged ideas on the nature, specifications, objectives, and goals of this AR scenario and its potential implementation in intercultural exchange. Drawing on Kerawalla et al.'s (2006) principles, the proposed scenario was intended to be aligned with the content of the curricula across academic institutions, students' needs, and AR activities. Considering that the students in this project were pursuing degrees in education, the proposed scenario was intended to have implications on education and the teaching profession. Migration and the lack of linguistic and cultural skills, which are a vehicle to employability, social inclusion, and equality, could be addressed through an interactive AR scenario featuring an alien landing on earth. An alien, with simply a small luggage and no other personal belongings, emulates the experience of many migrants

crossing across the European boarders of member states, striving to build a secure, politically stable, and socially acceptable standard of living. The aim was not to explore the root causes of migration but rather to guide students across participating academic institutions in understanding the importance of language and culture in this social integration and acculturation process. At the same time, students could interact with the alien scenario, receive written directions, and guidelines and provide written reflections on salient cultural artefacts that an immigrant might need to navigate through the target culture.

Once concluded that this scenario would be implemented to mediate intercultural exchange, the possibility of involving students in the selection of salient cultural artefacts that would be required by a migrant was explored. The team perceived this as a step to motivate students to become more creative and engaged in this process by contributing to the design and development of the AR scenario and sharing their ideas and views on what constitutes salient cultural artefacts. To offer students time to reflect on these artefacts and receive suggestions from students from both ends of project, a brief activity was posted on the Learning Management System, ReDesign, which invited students to think more critically about the kind of linguistic and cultural knowledge immigrants lack and to contemplate a migrant's perspective. The core focus was on developing culturally-responsive learning experiences where students could share salient cultural artefacts and explore the cultural artefacts provided by their peers in different geographic locations. This process also enacted affordances for contributing and actively participating in the design of AR applications. Instead of simply using AR applications, this community of students could also participate in the design process. The dynamics shifted: instead of being end-users of a particular technology, suddenly students were thrown into the thrust of identifying constructs that could guide the design of this game-like scenario.

7.4 Phase four: developing a prototype of the AR scenario

Following Klopfer and Squire (2008) and Maher and Ingram (1989), a prototype of the alien scenario was designed using the Unity game engine. It was designed for mobile devices that ran on the Android operating system. By leveraging the Unity game engine, the goal was to initially design and develop the visualisation and then to test the AR prototype scenario to ensure its functionality. Overcoming all technical challenges was a key factor in its implementation in order to shift students' attention to the actual activity. An AR marker of the project's logo, ReDesign, was designed using Adobe Illustrator and added to the scene. The AR camera and a target image were added in Unity's project for the AR system initialisation and operation. Image features from the existing ReDesign image marker were detected by the device's AR system.

Diving into the technical aspects of the AR system, the device's sensor data performs the detection and inertial measurement unit (IMU), constructs/maps the surrounding real environment. For example, it performs world tracking and scene estimation, in which the virtual object is placed at precise coordinates. The IMU contains several miniature gyroscopes and several miniature accelerometers, and can measure both linear and rotational acceleration. Therefore, it can provide information on the exact direction the device is oriented. It often includes a magnetometer that can be used by a mobile device to identify the north direction in order to provide Inertial Pose Tracking. This step can offer a prediction either of the orientation of the IMU or of its pose mainly because it

uses acceleration to infer changes in orientation. However, in combination with the noise, inherently produced by the hardware parts, reading on its own is not reliable. Simultaneous localisation and mapping (SLAM) is a way to periodically address and overcome these predictions and IMU-based tracking, which can provide a way to stabilise tracking for AR. As illustrated in Figure 1, the main scene was designed to feature an alien landing on earth, along with his cocoon. The alien was holding a suitcase with the project's logo inscribed on it.

Figure 1 Prototype of the alien scenario (see online version for colours)

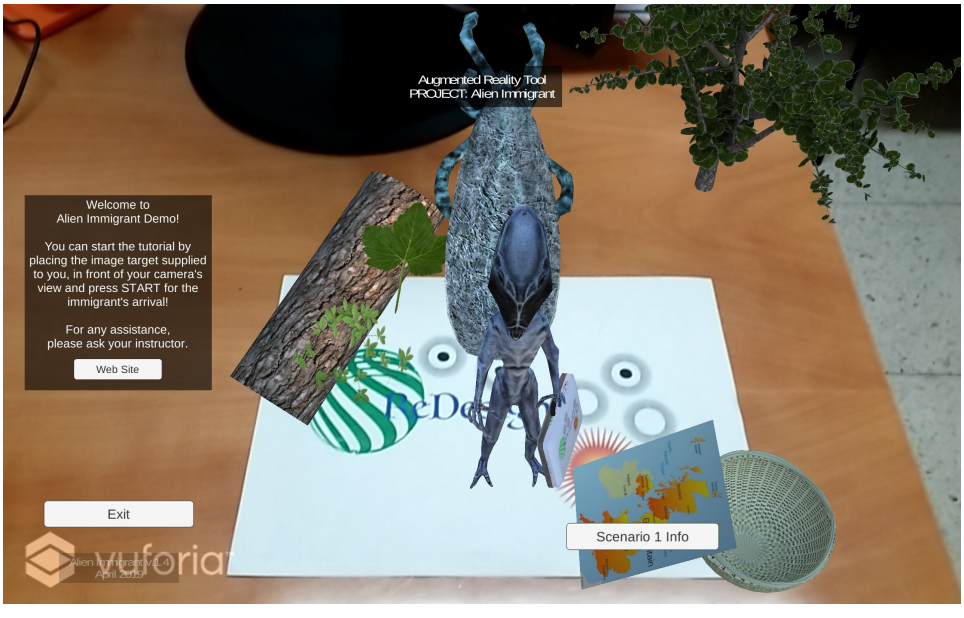
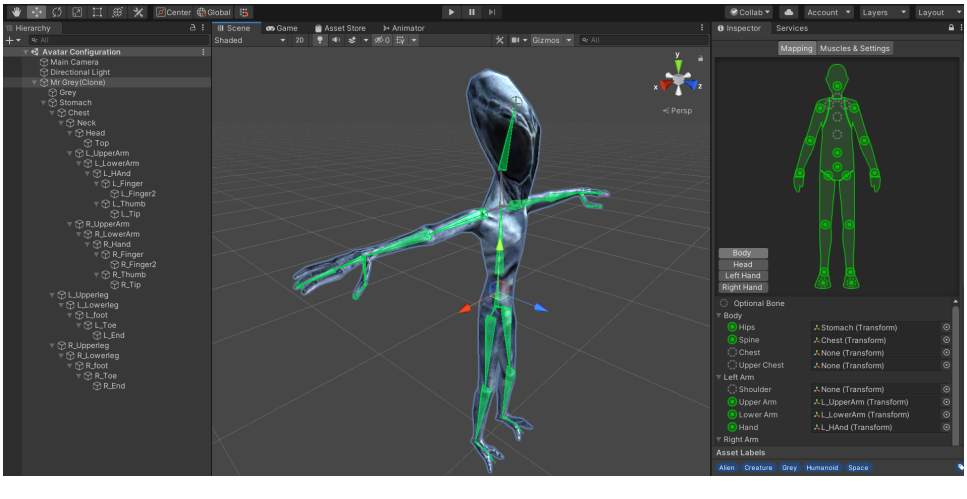


Figure 2 Animation of the alien scenario (see online version for colours)



Various 2D and 3D assets were downloaded from Unity's Asset Store, such as a tree and a large log. Properly trimmed audio (introductory music and alien speech) were used to enrich the 3D scene. Unity's character prerecorded animations (MOCAPs) were also imported to create an interactive, lively, and realistic main character. Six customised motion clips from MOCAPs animation data sets were deployed to render natural movement in the main character. Different animation clips were also blended to create a series of animations and restrict the animation to specific body parts, for example, by applying avatar masks. This step helped develop the required motion and avoided alien mesh interpenetration. Calibrations were applied to overcome this challenge. The cocoon was also animated by manually creating a keyframe motion clip. Both the main character and cocoon animations were initially programed to be paused, for example, by setting their animator's speed to 0, and in cases when the START button was pressed, the speed was set to 1, which is the normal playback speed. Certain online tools for image processing such as LunaPic, for changing 2D image resolution, adding transparency, and geometrical operations were also used. Unity's Forward Rendering technique was selected for low hardware requirements, because the AR application was designed to run on mobile devices and not on high-spec systems. Performance was contingent upon the number of lights used in the scene mainly because of the use of this specific technique. Therefore, these were kept to the minimum satisfactory visualisation level for effective scene illumination, graphics, and smooth alien character's animation, simultaneously ensuring uninterrupted interactivity between students and AR elements. Further, a set of guidelines was added welcoming students to the initial scenario and guiding them to start the tutorial.

The metaphor of an alien was designed to engage students in fun but thought-provoking discussions on culture, language, and their role in their everyday life. However, this goal would be achieved through an interactive AR-mediated experience. Students were informed that some of their proffered artefacts would be created in either 2D or 3D and would be rendered into the AR scenarios.

7.5 Phase five: testing the scenario and adding functionalities

To optimise the functionality of the AR application and to offer an engaging and immersive experience to all students, the initial scenario was tested by members of the design team, instructors, a researcher, a highly adept Dutch teacher trainer, and five instructors in various other disciplines that were not part of the design team but had an interest in either teaching or in Computer Assisted Language Learning. The aim of these trials was to:

1 test the functionality of the marker-based AR, including stability, position accuracy, and hardware support

2 determine participants' response to the use of this AR scenario, such as level of engagement, interaction, and participation

3 determine additional ways to align this activity with curricula across academic institutions and engage students further with this process

4 add interactive scenarios to guide students in exploring AR as a tool to enhance their learning and intercultural telecollaboration.

In this initial scenario, the need to use advanced rendering techniques to improve the visual quality of the alien was discussed. The scene's stability and robustness also called for further improvements in order to deliver a stable tracking system and enhance the accuracy and speed of the camera tracking system. Further, this step would help implement interactivity with objects in the real world, as well as place objects, interaction components, and non-photorealistic rendering to generate high quality virtual images which could be easily adapted to the real environment. The goal was to produce a sharp augmentation of an alien image animated on a visual marker featuring realistic animations and configured to facilitate walking, talking, and other natural, realistic human animations and movements. Importing additional prerecorded animations (MOCAPs), further animation and customisation were used to design an alien that resembled a warn and sympathetic character that did not present a threat to society. To the contrary, students could easily associate with this friendly and amicable character.

Initially members of the consortium, an experienced teacher trainer, and five instructors were invited to interact with the AR scenario, to share their feedback and provide specific suggestions for its improvement. Multiple follow-up virtual meetings were held to tailor the visual elements of the alien scenario and to offer a perceptually rich learning experience to students. Observations and feedback suggestions mainly focused on the novelty of the AR scenario, possibilities for its integration into the curricula across academic institutions, and students' involvement in the design process. However, students' contribution to this process would not be hindered by the lack of programming skills required for AR development in the Unity game engine. A well experienced software developer would develop the culturally and linguistically salient artefacts for the students. During the virtual meetings and written feedback, proffered suggestions mainly focused on the following areas:

a further customisation and animation of the virtual alien and artefacts in the script

b adaptation of the virtual alien to the real world environment and relevance of the content

c student involvement in this AR scenario through activities that promoted intercultural telecollaboration and understanding and student engagement

d implementation and configuration of virtual buttons to invoke interactivity and offer students guidelines on their next steps

e sound design to enrich the scene and place students in the shoes of the alien who neither spoke the target language nor was familiar with the target culture.

Building on the proffered suggestions and feedback, in addition to the introductory scene featuring the alien landing on earth with a suitcase, two interactive scenarios were then built:

- *First scenario:* a friendly, approachable alien using an unfamiliar non-human like language to greet users.
- *Second scenario:* an invitation to students to identify and share linguistic and cultural artefacts to begin the acculturation process.

Virtual buttons were also added to each scenario to enhance interactivity, guiding students in navigating through the scenarios by offering guidelines and directions on the next steps they would need to take.

The program code was written based on each scenario's logic flow, designed from the feedback obtained and students' learning. Making decisions on the kind of game objects to be placed on the screen and the ones to be removed, the ones to be animated and the ones to remain static, and blending them with user interactivity, required significant testing time and skills. AR-mobile development application is based on a completely different approach than a traditional one, running solely on a mobile screen. Therefore, customisations and improvements were imperative to generate the required outcome.

7.6 Phase six: implementation during intercultural exchange

During the next phase, an activity was introduced on the ReDesign platform immersing students across academic institutions in an imaginary, out of space scenario where they needed to identify three cultural artefacts that they considered defining constructs of their culture. Students were also invited to provide an explanation to justify their selection of artefacts. Some of the proposed cultural artefacts would then be designed in either 2D or 3D. Some level of creativity and excitement was anticipated among students because they had neither been exposed to a similar intercultural experience nor had they been given an opportunity to contribute to the design of an AR scenario. The nature of the activity prompted students to reflect on their culture and to contemplate the role of cultural artefacts in shaping their culture and themselves. At the same time, students could invite members of another culture – in this case an alien – to explore these cultural artefacts and their cultural significance. Fantasy and reality were intertwined in an AR application with pedagogical implications. Students pursuing a teaching degree would encounter migrant children in their classes at both sites of the spectrum, in the UK and Cyprus. Due to its strategic location, Cyprus forms an attractive destination for immigrants. Similarly, the prospect of financial prosperity and employment makes UK a popular destination for migrants. Drawing on these constructs, this design phase was driven by the following goals:

1 Actively contributing to the design process of AR applications by sharing cultural constructs and values.

2 Prompting students to reflect on their culture and cultural artefacts as a path to introducing migrant children to the target culture in the future.

3 Becoming acquainted with and reflecting on other cultures, cultural artefacts, and language.

4 Viewing and interacting with the cultural artefacts in 2D or 3D through this AR application.

5 Understanding and experiencing the pedagogical implications of AR in learning and its added value, especially during intercultural exchange.

In the spring semester of 2019, the AR application was implemented during intercultural exchange among students at two large public academic institutions in Cyprus and the UK. Participating students first explored the alien scenario and then identified at least three cultural artefacts that they perceived salient; for example, cultural icons such as the

queen; sports such as football; food products including kolokasi (a type of sweet potato) and cheese; and a wide variety of other artefacts including language, literature, and architecture. Students admitted that they were excited by the prospect of viewing in AR the artefacts that they proposed, so they strove to be creative, entertaining, innovative, and original. They proposed either well known artefacts that represented their culture or less commonly known artefacts, such as kolokasi. Most students laughed and giggled in class as they shared the artefacts that they proposed.

Then the research team proceeded with the following changes:

a Two additional scenarios were added. In total, three scenarios were designed:
   - *First scenario:* an alien lands on earth and uses a non-human language to communicate with students.
   - *Second scenario:* in a friendly, welcoming gesture, the alien is introduced to the target culture through various Cypriot and English artefacts.
   - *Third scenario:* in return to this warm welcoming, the alien presents a family photo as a friendly gesture.

b As indicated in Figure 3, based on students' suggestions of cultural artefacts, additional 2D and 3D objects were either designed or added to the scene from Unity's assets library. Some of the free online assets included:
   - 2D objects: a crown, a British bus, language, history, and an architectural image featuring iconic monuments in the UK, including the Buckingham palace, the London Bridge, and London Eye.
   - 3D objects: sand, kolokasi, and a bus.

     In the case of kolokasi, which forms an integral part of the Cypriot cuisine, photogrammetry software, 3DF Zephyr was deployed to create this local sweet potato from the actual physical object. 2D images from 360 degrees photos of an actual object, kolokasi, were taken to reconstruct it as a 3D model.

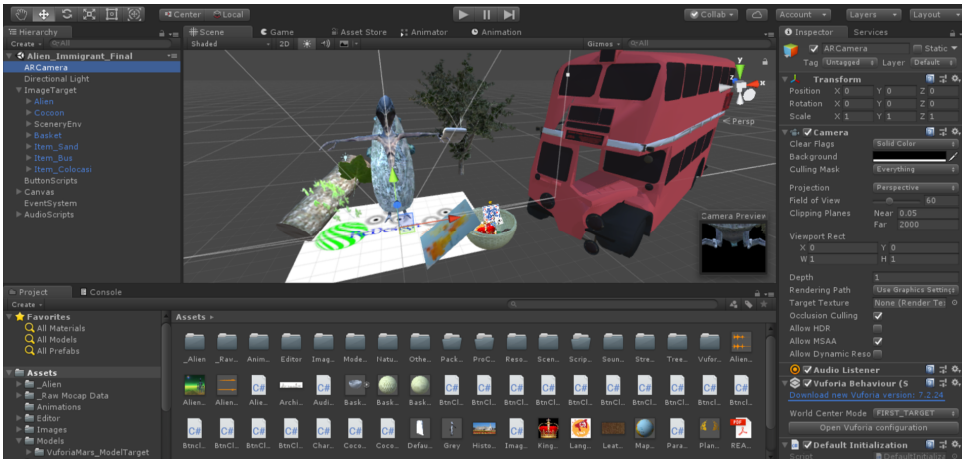
c The online image editor, LunaPic, as well as geometrical operations, was used for image resolution, opacity, and transparency. Deploying the required scaling tools, the images were scaled and resized using custom parameters. The quality of the image was also optimised to enhance user experience.

d User-interface items such as virtual buttons, touchable images/photos were created as a mechanism to promote interactivity and offer specific directions and guidelines to users on how to proceed to the next scenario. In total, 20 user-interface items were created.

e Further, MOCAPs data were used to ensure coordination between gestures and non-human speech as the alien tried to communicate with students.

f Audio files from online free assets websites were imported and adjusted to be loaded at runtime to enhance user experience, elicit an emotional response, and set a rather relaxing, friendly tone.

Figure 3 Unity interface – game objects (GO) used in project (top left), scene editing (middle), GOs' properties (right), project's assets/objects (bottom) (see online version for colours)



7.7 Phase seven: future steps for expansion

Insightful reflections on culture were placed at the core of intercultural exchange, while novel AR scenarios were designed and deployed to mediate the exchange. Though this was an imaginary alien application, students could intelligently interact with the AR scenarios and experience culture in 2D or 3D contexts. This multiuser AR application, along with the collaborative activities, disrupted the traditional college learning experience by enacting experiences and interactions entirely different from past formal learning experiences. Even though it was a fairly simple customisable scenario, with students' active involvement and contribution to this design process, as students became more acquainted with AR technology and had an opportunity to explore its pedagogical potential, their expectations increased. Students expressed the need for further integration of AR into different learning contexts and for more advanced and complex AR scenarios. They envisioned a multiuser game-like experience that was richer, more demanding and engaging. Students' proffered cultural artefacts were driven by their attempt to immerse migrant students to the target culture. However, history, and cultural practices and values could be contextualised and situated in scavenger hunts or collaborative explorations unfolding in richer 3D contexts.

Members of the research team acknowledged the importance of integrating 3D historical sites into academic curricula and intercultural exchange, so they decided to pursue new paths for enacting entirely new immersive learning experiences in AR. In collaboration with a software developing company in Cyprus and a museum in Kalmar, 3D models offering a digital reconstruction of popular and historically rich sites in Cyprus and Sweden were identified, such as the Tomb of the Kings and Sandby borg, Öland. Photogrammetry-based 3D models of salient cultural artefacts were also identified to offer a cost-effective solution, within a rigid timeline. The 3D models could enact more dynamic, interactive multimodal contexts which could facilitate first-hand interaction with salient cultural sites, inviting students to explore the historical and cultural significance of each site and examine their contribution in moulding society,

history, and culture. Discussions on cultural artefacts would also form the underlying mechanism for understanding cultural practices, beliefs, behaviours, and values; reflecting on such culturally salient practices; and taking a critical look at the historically important values and practices of their own culture.

To embed these experiences in intercultural exchange, the trajectories of intercultural collaboration were also extended by inviting scholars from different disciplines to join this endeavour. A small pool of scholars specialising in cultural heritage in an academic institution responded to this call to promote exploration of different civilisations, history, cultural practices, and language through the use of existing 3D models. These newly introduced 3D elements and cultural artefacts would also need to be accompanied by pedagogically demanding, goal-driven activities. The activities would generate constructive discussion on cultural understanding and would contribute to language learning, interaction, and challenge of cultural stereotypes. The research team envisioned exchange of cultural artefacts in each historical site generated in 3D, which would aim to engage students in collaborative problem-solving activities, reflections on culture and exploration of central characters and figures, as well as the artefacts of that era. At the same time, real-life interactions in these 3D models and exploration of AR-mediated artefacts during intercultural exchange would promote further cultural understanding and collaboration. For instance, students would be invited to collectively identify cultural artefacts that could be used to enrich the 3D scene and discuss their cultural relevance. Students could exchange these cultural artefacts with their peers – this step would help take the intercultural experience and interaction with AR even a step further that has not been explored yet.

8 Discussion

DBR can be employed as a framework to expand beyond the local institutional trajectories to involve a rather global context by promoting interventions that are mediated by novel technologies and are driven by an interdisciplinary pool of scholars and professionals to transform students' learning and teachers' teaching practices. This study indicates that DBR can extend beyond interventions that have an impact on "individual teachers and schools" [Anderson and Shattuck, (2012), p.24]. DBR can be extended to include intercultural exchange and involve an interdisciplinary transnational pool of scholars, professionals, and students. However, instead of zooming in the different tools and applications, focus should be placed on the iterative processes involved in developing and deploying tools and applications that can form part of the ecosystem in which they are implemented. As Barab (2014) notes, "we should engage stakeholders and implementation facilitators as collaborators whose potential actions can become part of the design in situ" (p.161). The design interface described in this study draws on seven phases. It involved a rather comprehensive and inclusive approach which was driven by principles of full participation and engagement of the indicated team in different phases of this design framework.

Instructors' participation in the prototype design and development and students' contribution to the design of the follow-up scenarios were nested in a collaborative endeavour mediated not simply by novel technologies but also by participants' cultural practices and conceptualisations of what constitutes and defines their culture. The ecosystem promoted was guided by contributions which were embedded in the broader

global and local context and were realised through task-oriented activities mediated by AR technologies and cultural practices. The initial scenario was enacted on specific tasks and goals and not just tools for entertainment and exploration of AR applications. This process empowered instructors by offering them an opportunity to acknowledge and raise sociopolitical challenges that also enclosed implications for their teaching practice. At the same time, students' contribution to this process offered them an opportunity to experience learning beyond the abstract or complex knowledge to which students are often exposed to through formal education. Instead, this activity guided students in contemplating the multidimensional value and complexity of culture, identity, and their society. artefacts, whether in AR or in real-life context, are constructed and mediated by rich historical, cultural, and social traditions that mould one's values and life. These artefacts designed in 2D or 3D format formed an exploration of culture, the way it is formed, practiced, and conveyed to members of another culture.

Nevertheless, as the study indicates, the iterative processes involved in designing these 2D and 3D models were demanding and often complex. Involving students and an interdisciplinary pool of participants enacted cultural and technological tensions with the research team and software developer. On one hand, students' engagement in the design process guided in pursing novel approaches to design in 2D and 3D the artefacts and scenarios. On the other hand, it turned these iterative processes into more demanding and creative and generated some technological tensions. Thorne (2003) and Basharina (2007), for example, indicate that mediational artefacts can enact both affordances and tensions. Constructing students' proffered objects in 3D objects required the use of photogrammetry software, while image resolution required the use of tools for image processing. Adding interactivity, importing MOCAPs, and assets from the Unity assets library warranted the need to constantly deploy new software to deliver the required outcome. This process required not only knowledge of specific software and programming language, such as C#, but also creativity and imagination. Therefore, the design of AR applications with teachers' and students' active contributions added to the already demanding design process and required the pursuit of new paths to realise the goals set in the artefact design. However, this bottom-up approach opened the path to end-users to engage in this process and offer a new perspective in what constitutes and how students define not only other cultures but also their own culture. The design-based lens, then enacted affordances to capture and articulate both the stages and tensions which guided in the development and realisation of the AR scenarios.

9 Conclusions and pedagogical implications

The DBR landscape is constantly changing and enriched by interdisciplinary approaches in both theory and research. New technologies and approaches to enhance users' learning expand the ways of pursuing DBR by placing the focus not on the end products but on the end-users and their needs. It is a demanding, complex, and thought-provoking process. Constant evaluation of the design features is imperative to promote functionality and interactivity between the physical and virtual environment. However, the pedagogical value and potential of each tool and the prospect of engaging learners in the learning process and guiding them take a closer look at their culture, values, and language can guide in knowledge construction and cultural understanding. As a result, the pedagogical value of each technology, including AR, should be explored further; for instance, during

intercultural exchange where the implications have not been fully explored. This process could shed some light on the processes and practices involved in designing, developing, and deploying a novel AR application during intercultural exchange. Most importantly, a better understanding could be developed on students' and instructors' perceptions of culture, salient cultural artefacts, and values. This step could contribute to bringing to the curriculum more culturally salient areas and enhancing cultural understanding. Technology could be exploited as a tool through which these cultural constructs and values are explored, constructed, and moulded. To this end, large-scale interdisciplinary collaborative endeavours should be launched to develop culturally and technologically relevant curricula to enrich students learning and guide them in building digital skills and knowledge to compete in the global labour market. Contradictions and tensions should be anticipated and addressed through steps and actions that will guide in enriching learning and teaching experiences and at the same time assist in building digital skills. Meaningful implementations should be explored and described to offer a glimpse into the underlying processes unfolding. Then by leveraging some of the underlying mechanisms which guide the enactment, implementation, and realisation of these learning activities and their mediational means, a more conceptual understanding will be developed on the nature and impact of these interventions.

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