Building an augmented reality system for consumption and production of hybrid gaming and storytelling

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Abstract. This article provides an overview of how augmented reality (AR) can support gaming and ludic experiences. More importantly, it describes the development and open access availability of an augmented and virtual reality platform called GLARE that can be used to create hybrid storytelling and gaming experiences. In doing so, it provides insights of how we can move from a consumption-based (educators and students exposed to AR content) to a production-driven (educators and students creating AR content) approach to improve the pedagogical and psychological outcomes of such a technology. Concrete examples are provided to contextualize such a potential.

Keywords: Augmented Reality, Gamification, GLARE, Media Consumption, Media Production, Hybrid Storytelling

1 Introduction

While digital gaming has seen mass acceptance and popularity across many fields recently [1], analog gaming has been used for centuries [2]. Both analog and digital game use has been broadly tied to psychological and pedagogical frameworks underlying the importance of the construct of play [3]. For instance, Burris and Tsao argue that play can lead to creativity, joy, learning, and even better interpersonal relationships [4].

There have been at least two large and recent movements related to this interest in game-based play [1]. The first has been an increase in social gaming and the social supports surrounding game play (i.e., game streaming, game communities) [5]. The second has been an increase in augmented reality (AR) [6] or hybrid gaming [7] [8]. Hamari et al. [7] suggested that people play AR or hybrid games (e.g., Pokémon Go) for multiple reasons ranging from the importance of socializing to competition, and from getting outdoor activity to simple enjoyment of the types of available games.

This rise of interest in AR or hybrid games also touches on the first movement because of its inherent social nature.

There are several challenges with AR and hybrid games. Challenges can include, for instance, emotional conflict with the game or even technical and technological issues in engaging with the environment [9]. They also include concerns about accessibility and inclusion. One of the larger problems, however, is the ease with which developers can create AR and hybrid stories and games.

The purpose of this paper is to describe the development and implementation of an augmented reality development tool called *GLARE*. GLARE was created to respond to the need for developers to easily implement digital content into live settings. Several examples are provided of using the system to be able to conduct hybrid storytelling. While this system has not yet been implemented directly for digital gaming, theoretical examples from both gaming and gamification are provided. The paper ends with a recommendation for understanding the productive—rather than just the consumptive—value of AR and hybrid gaming and storytelling.

2 Literature Review

2.1 Augmented Reality (AR) and Hybrid Gaming

There is a long and storied history of the use and implementation of analog and digital gaming across multiple fields ranging from education to business and from computer science to history [1] [2]. Augmented reality or hybrid digital gaming, more specifically, saw a significant rise of interest in 2016 with the release of *Pokémon Go* [7]. Whether they are referred to as location-based games (LBGs), augmented reality games (ARGs), or hybrid games, their popularity is due, largely, to the gratification people receive from play. Such gratification can include social benefits of engaging with others [9], getting outdoor activity [7], and even a deeper connection to and awareness of ecology [10].

Hybrid games can be interpreted as a combination of real world and AR components. These games build on the interplay between analog and digital features that can promote engagement, learning, and interest. For instance, researchers have developed mobile-based board games to help students get scaffolding and feedback [38] (other examples include *Destinies* and *Chronicles of Crime* from Lucky Duck Games). This synergy can have important implications for storytelling instances, especially in terms of emerging narratives from gameplay sessions [39].

With the positive potential, however, there is evidence of challenges or dangers with LBGs and ARGs. For instance, such hybrid games might encourage negative interactions with nature (e.g., wildlife, trespassing) or even a decreasing desire to engage with real world nature [10]. AR gaming could also potentially cause emotional conflict, either due to the nature of the game or the technical and technological problems associated with such games [9]. Moreover, there can be many inclusivity issues with such games, regardless of whether such challenges are from the environment (e.g., wheelchair accessibility), the game (e.g., affordances for those with hearing or sight needs), or the blending of the game and environment [11].

2.2 AR and Hybrid Development Systems

The affordances and constraints notwithstanding, augmented reality and hybrid games continue to rise in popularity for both commercial and educational reasons and goals [12] [13] [14] [15]. The remaining but significant question for those without expansive commercial resources is how to easily develop and implement AR or hybrid storytelling and games.

Commercial software does exist and has existed for some time. For instance, Hewlett Packard developed an augmented reality tool called *Reveal* (formerly *Aurasma*) for helping users create and engage with content [16]. Other examples include *Quiver*, *ARCore*, *ARKit*, *Vuforia*, *ARToolKit*, *Unity*, *Unreal*, and *Wikitude* [also see 17]. Such tools provide a way for creating marker-based (e.g., QR codes or objects), marker-less (e.g., GPS or depth-sensing tools), or location-based (e.g., Bluetooth or Wi-Fi) AR and hybrid content [18].

There are at least two challenges with these and other AR tools. First, many of them require extensive coding experience. This requires costs for hiring developers [19]. There is software that is more accessible for non-coding savvy users. The second and related issue, however, is that this software is often very specific in its purpose. Moreover, few of those software titles are generalizable, open access, or adaptable.

Given these needs, many scholars have attempted to create their own AR or hybrid systems. An example of this comes from the work of Vidal-Balea et al. [20]. The research team used *ARCore*, a *Django* and *SQL Lite* backend, and a *Bootstrap* frontend (with HTML, JavaScript, and other software) to create a tool to support pediatric healthcare. Other authors have created similar systems for implementing and testing an AR puzzle app [21].

These scholars have completed thoughtful and creative processes to develop and test AR-based apps and games. What is apparent, however, is that while most have used open access tools, there was still significant development required. Roberto et al. [21], for instance, highlighted the need to navigate various components such as software development kits (SDKs), tracking, end use platforms, graphics, cloud computing, and GPS navigation. This can become even more complicated when integrating haptics [22].

The concern and the opportunity, therefore, was to develop an AR or hybrid gaming and storytelling system that would accomplish four tasks. First, it would be freely accessible. Second, the system could be used by any user, particularly those with limited coding skills. Third, even though the system would be intended to be used without coding, it would be openly accessible through *GitHub* for those users that needed further adaptations for their end use case. Finally, and perhaps the biggest challenge, is that the system would need to be hybrid (i.e., augmented reality) while still allowing accessibility to all (i.e., virtual reality for those who could not physically attend the real-life component. These four goals became the basis for building GLARE.

3 The Geo-Located Augmented Reality Editor (GLARE)

3.1 Description of the GLARE Editor

Geo-Located Augmented Reality Editor (GLARE; https://glare.cs.kent.edu) is an Extended Reality (XR) open-source web-based application that provides robust editability for tele-tourism. GLARE is designed to be data agnostic and a platform for end-users to visually design location-based tours with rich media content (immersive 360 images, audio, links and 3d meshes). It was developed as a user-friendly online tool to allow users to design, develop, and deliver AR experiences to the public. GLARE allows AR developers to select places of interest (also called hotspots) and associate those locations with extended reality media like 360 pictures and AR overlays. Moreover, creators can include additional content like audio clips, images, and text to enrich and contextualize hotspots and the stories and activities they represent. These efforts do not require any programming expertise; individuals with no coding skills (e.g., elementary-aged students) can easily build AR stories with GLARE through an accessible Graphic User Interface (GUI).

Once creators have picked hotspots and added content to their locations, GLARE produces an AR tour that is composed of the hotspots and related materials. These tours are accessible through a URL automatically generated by GLARE. As such, the product is platform agnostic; end-users do not need to download any application or own a certain device. The tour can be viewed through a web browser on a laptop or desktop, on a mobile phone (i.e., at the location), or even through a head mounted display (e.g., *Oculus Quest 2*).

This is also true for developers. GLARE is an open access and free online editor that does not have any requirement in terms of software and hardware; only a working internet connection is needed to use it and access the tours developed with it. However, developers that want to adapt the existing code can do so through its open access in *GitHub* (see section 3.4).

GLARE is designed to deliver AR experiences that can be accessed both in-situ and remotely. If end-users are physically close to the hotspots' location, the related content (e.g., the AR overlay, content) will be visualized on their mobile devices' live camera. If they are not close to them, a 360 picture will be displayed as a background for each of the hotspots. This flexibility allows AR developers to use GLARE to serve different purposes, from augmenting a real location to attracting people to a targeted place. Moreover, it promotes access and equality for users who cannot be physically near the AR tour. Prior to further explaining the technological components behind the system, examples of GLARE projects are provided.

3.2 GLARE Hybrid Storytelling Example #1: Kent, Ohio

The Kent State Massacre (Kent, Ohio, United States) occurred on May 4, 1970, when 4 students were killed, and 9 others were wounded by Ohio National Guard. The shootings happened during a student protest and is considered to be a culminating, historical, pivotal moment in modern American History [23]. The event has long lasting implications for U.S. First Amendment Rights, the excessive use of government force, and the importance of younger generations seeking to make a difference.

There are a few main challenges in educating younger generations about the importance of those events. First, they do not necessarily see the connection or correlation of things that happened 50 years to events in their life today. Second, it can be difficult to tell a story of those events, particularly on campus, as many of the buildings relevant to the shootings no longer exist today. So, while students or visitors to campus can still see bullet holes, the ROTC building that was burned down (thus leading to the National Guard control of the campus) no longer exists.

In response to this need, the U.S. National Endowment for the Humanities funded the development of a "May 4th Augmented Reality Tour" (as well as GLARE as a system to support this and other tours). The tour hosts three different hybrid storytelling experiences (see Figure 1) including a tour of relevant, historical locations (i.e., blue dots numbered from 1-7), a tour of the places where students were killed or injured (i.e., yellow dots lettered A-M), and the location of the National Guard (i.e., the orange X).

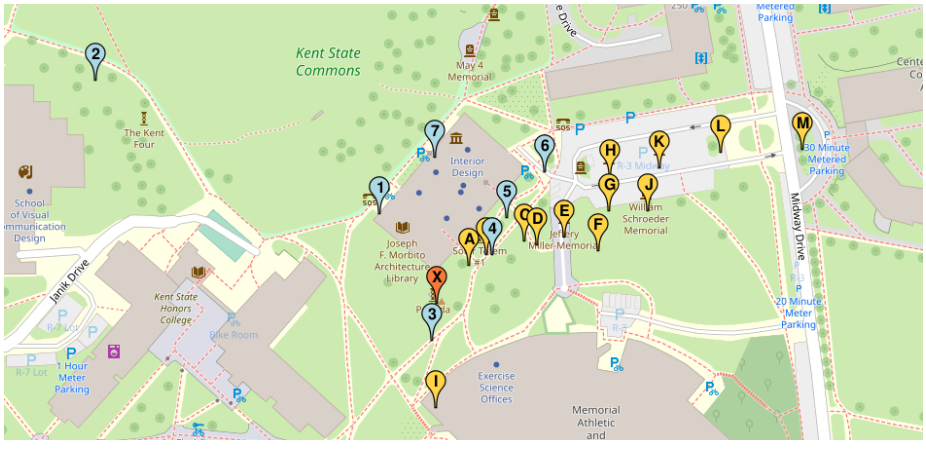

Fig. 1. Map of several hotspots in the May 4th Augmented Reality experience.

For the blue historic location tour, visitors can stand, for instance at the Victory Bell (location 1) and see images of the 500 students who gathered the first days of May. They can also walk to the now empty site of the ROTC building and visualize images of where it stood before it was burnt down on Saturday, May 2nd. Figure 2

shows a user who has arrived at the location and is looking through their camera to see the current location with the historical image overlay. Figure 2 also shows how a voice recording begins when the user reaches the spot, explaining to them the content and the importance of the location in the story.

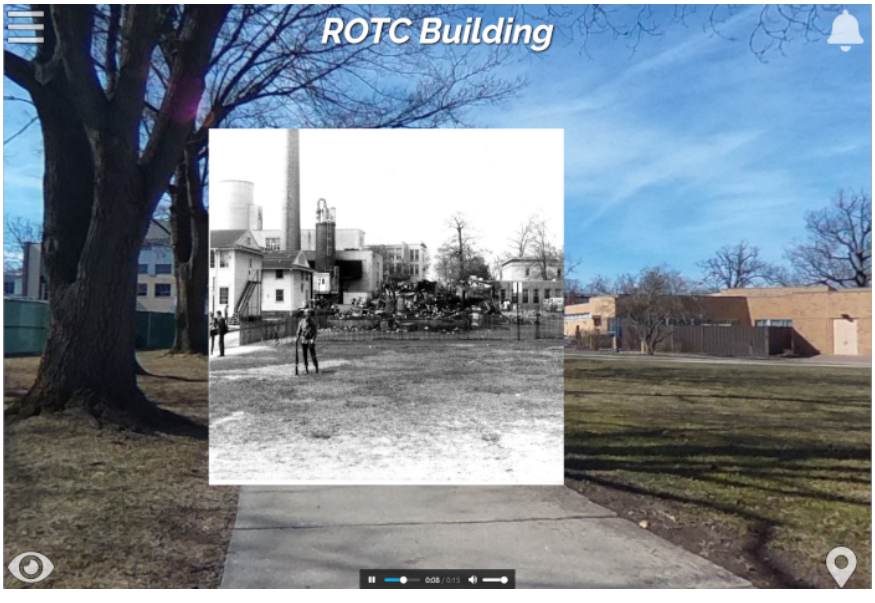

Fig. 2. Example of a historical image overlaying a current camera perspective.

For users who were either on Kent State's campus or alive at the time of the May 4 events, the app serves to refresh their memory and spark a dialogue into the nearly fifty-year struggle to interpret difficulty history. But one of the main goals of the tour was also to introduce guests new to the events or students who were not alive at the time to the historical importance of May 4, 1970. This includes learning more about the transversal impact of May 4, understanding how protests of the 1960s mirror those today as they serve as bearers of activism, engage in questions about government involvement, and how to support memory and commemoration over dramatic past events. To do this, the hybrid storytelling experience also provides multiple references and sources tied to these objectives. By clicking on the hamburger menu in the upper left window of any location, a user is presented with a menu (also created in GLARE) that provides them with additional information (see Figure 3). The May 4th AR tour includes the context leading up to May 4, what happened on the actual day, how that location is commemorated, questions for the user to consider as they reflect on voices for change, and a library of additional materials (e.g., more pictures and audio clips) to support their inquiry.

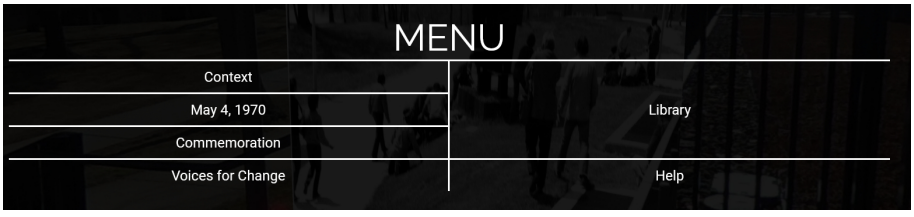

Fig. 3. Example menu system for the augmented reality experience, highlighting both the library and the opportunity to learn more information by category.

3.3 GLARE Hybrid Storytelling Example #2: Florence, Italy

The *May 4th Augmented Reality Tour* builds upon a need for historical and hybrid storytelling. As such, GLARE allows for content creators to map historical pictures as overlays onto existing camera perspectives (or current pictures for those viewing the tour off campus). Not every situation requires a historic perspective.

For instance, many foreign universities have a summer home in Florence, Italy. Universities, therefore, have a desire to have students become acclimated to the foreign setting in order to best accomplish their educational goals and pursuits. This can occur through large tours using whisperers (i.e., tour leads with microphones and visitors with headphones) or through orientations prior to departure from their home country. While such introductions can be useful, students often complain about the ability to hear on the walking tours, the ability to revisit content, or the realism of the pre-departure orientation (i.e., not feeling like they are present in a foreign land).

Drawing on these concerns, a *Florence Augmented Reality Tour* was created using GLARE. It provided an opportunity for users to see important landmarks in Florence such as the Ponte Vecchio bridge, the Duomo and Baptistry, and the Misericordia. However, unlike the May 4th exhibit, the goal was not necessarily historical in nature. Content creators wanted viewers to understand the context and importance of the locations, but there was not the same need to see overlays of historic pictures. Figure 4 shows an example of a user at the Ponte Vecchio bridge, looking down the river and also across to their right (in the 360 image).

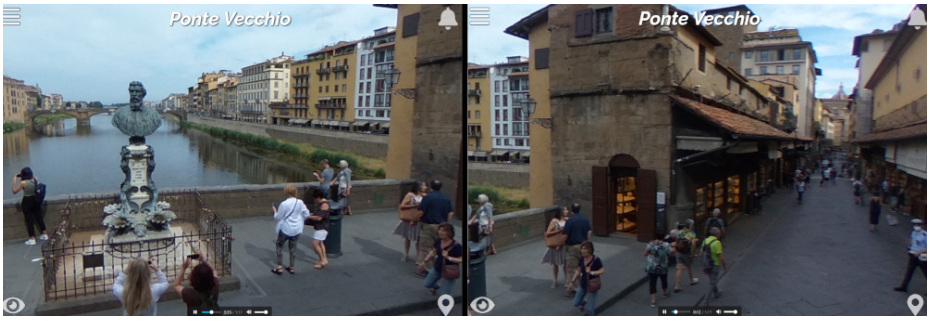

Fig. 4. A 360 degree view of the Ponte Vecchio bridge in Florence, Italy.

The feasibility of using GLARE without historical overlays does present an interesting storytelling problem related to augmented reality. If the person is not in the current location (i.e., they are using this for orientation prior to arriving in Florence), the 360 image gives them a feeling of presence or of actually being there. But users in the location (i.e., on the Ponte Vecchio bridge) might find little value in loading the system and seeing a similar image to what they currently see.

GLARE solves this storytelling dilemma through its menu offerings. Figure 5 shows a similar (coincidentally) menu structure with four menu items offered to participants at a hotspot location. These include understanding the importance of the location to the city of Florence and to the university hosting these students (i.e., Kent State). It also includes both faculty and student voices and stories, so that users can hear what others have experienced while standing in the same location. Finally, it includes a library of other images and voice recordings, so that users can choose to take deeper dives into content areas regarding the location.

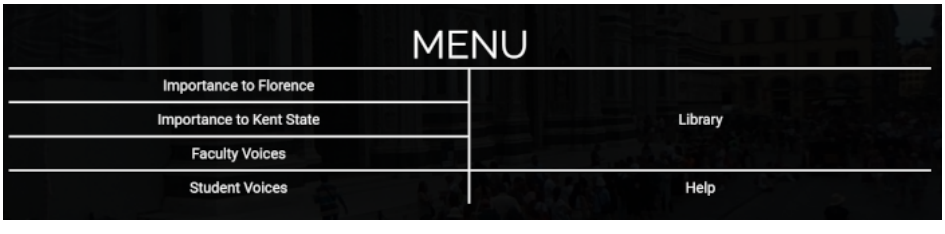

Fig. 5. The menu system for the *Florence Augmented Reality Tour*.

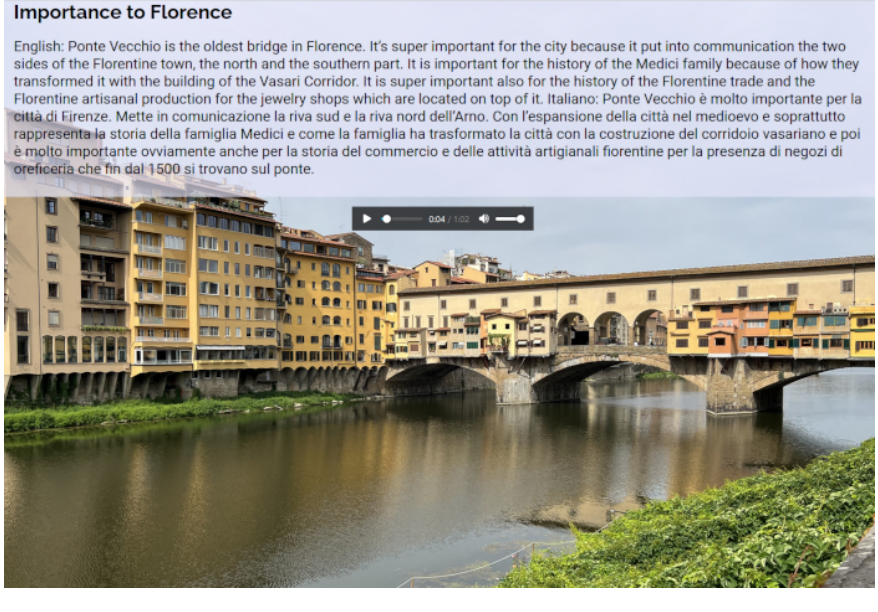

Fig. 6. Bilingual information regarding the Ponte Vecchio in Florence, Italy.

Figure 6 contains an image and description of one of those menu choices. In this example, the user has chosen to learn about the importance of the bridge to the city of Florence. Once again, this experience is meant to be both hybrid and multi-modal. As such, while users are standing on the bridge, they can hear descriptive recordings in both English and Italian (as a particular way to climatize users who have not arrived yet). They can see images that point them to look in various locations.

3.4 GLARE Infrastructure

The examples have been made possible by GLARE's infrastructure, which is driven by accessibility and usability drivers [24]. Specifically, GLARE is broken into three main components:

- The GLARE Editor and Database. For editing, generating, and hosting of XR projects which is accessible from a website frontend. This portion of GLARE includes an interface for creating a tour and uploading associated media to a user account on the main database. The containerized database managed through docker permits users to create new and edit existing tours associated with their account that are hosted on the GLARE server or can be downloaded and hosted elsewhere.
- GLARE. The main project that handles the flow of the apps and the logic that runs within the browser exists as a React static website, written to be static so that it can be both portable and be run by any HTTP Server (IE Apache, Ngnix, etc.) or local browser and used in the editor and viewer. This takes the configuration file as input which is customized based on the created tour and any included user data. Essentially, the configuration is parsed and the HTML elements / React components to be displayed populated based on what is written in the configuration file.
- GLARE Viewer. This is a custom NPM package component for handling the XR (Augmented Reality - AR and Virtual Reality - VR) viewing experience for the user. This part of the project allows for the creation of AR or VR depending on the user's location. This is done by utilizing the library Three.js, which provides the ability to create and display 3D graphics using the browser. More technically, Three.js is a wrapper for the WebGL rendering standard of the browser. In order to maintain a react-like codebase, the react rendering library React Three Fiber was used to wrap around Three.js to provide a cleaner experience. In virtual reality mode, creating a virtual environment is done by generating a skybox using a panoramic/360 image provided by the users' configuration file. Viewers can control how the image is viewed by using the mouse or an "orbit controlling camera" to adjust the viewpoint and interact with the menu components. For augmented reality, the primary approach is to just pass through the real world through the camera and overlay the digitally generated images/objects. This overlays the camera pass-through underneath a sphere that is wrapped with an image so that it becomes directional. This allows the user to rotate/tilt their device,

using a device-controlling camera, to change their viewing perspective and what is rendered on screen based on gyroscopic sensor data.

GLARE's GUI-based editing tool is shown in Figure 7.

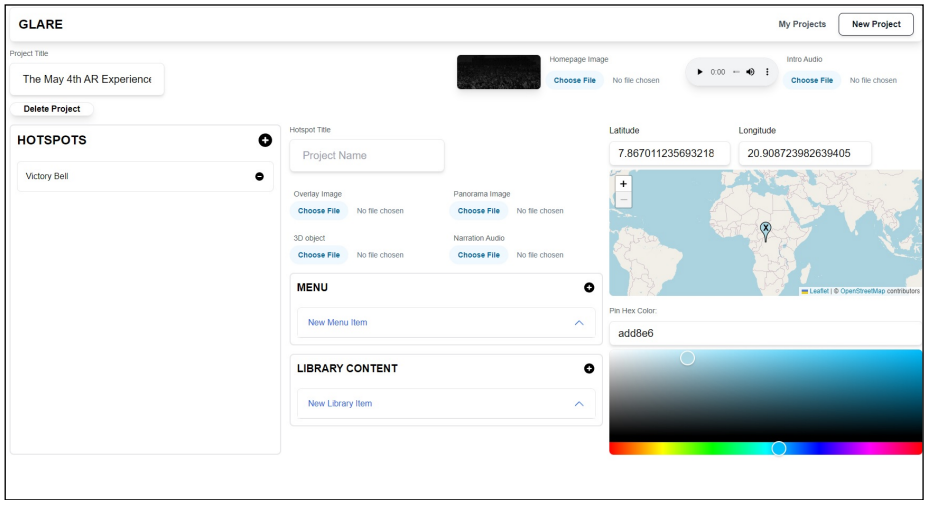

Fig. 7. GLARE's GUI structure.

AR creators are asked to name the hotspot they want to build. Then, they indicate its geographical location by simply clicking on the World map (GLARE generates the coordinates accordingly). Finally, they are able to upload the content that is going to populate the hotspot, among which:

- The overlay image, which is the AR overlay (3D object, picture) that will appear on top of the live camera (in-situ experience) or 360 picture (remote experience).
- The panorama image, which is the 360-picture visualized as a background for users who are not the in hotspot's physical location.
- The narration audio, which will introduce the hotspot and its importance in the context of the AR tour.
- The Create Link section, which is where users can add buttons to associate with the hotspot. By clicking on the buttons, end-users will access pictures, audio and text that expand the hotspot's scope (see Fig. 5 for an example).
- The Create Content section, which can be audio, visual, and text and work as a repository of materials that users see and listen to aside from what offered in the Link section.

AR developers can add as many hotspots as they want by clicking on the "Add a Hotspot" button (Figure 7, on the right). According to the hotspots' coordinates, GLARE will generate a map (see Fig. 1 for an example) and a related URL to access

it. For more technical information about the GLARE backend, please refer to Gandolfi et al. [24].

4 Discussion & Implications

4.1 Hybrid Storytelling

The May 4 and Florence AR experiences developed with GLARE are aligned with the potential of this technology to foster motivation, engagement, and learning [18] [21] [22] [25]. The combination of geolocated information and multimedia is indeed a promising strategy to inform hybrid storytelling instances between in-situ and remote experiences and between different media and sensorial involvements [24] [25]. As such, users can access and experience mutual connections between real and digital components around them.

It can be argued that this approach shows promise because it allows narratives to be situated and, therefore, be more authentic and meaningful [25]. At the same time, a hybrid storytelling lens promotes a more inclusive experience where everyone can benefit from its features by considering different mobility needs and learning preferences [6]. Finally, the GLARE-based narratives reported in this article aim at improving wellbeing and community belonging, which are among the main benefits that AR may have if properly designed [27]. Studies on this technology, particularly with the May 4 Augmented Reality tour, have also shown that users have a significant and increased sense of both situational interest and content knowledge about the location [25].

4.2 Hybrid Gaming and Gamification Using GLARE

GLARE does not currently have embedded game mechanics. Its focus has been on hybrid storytelling through augmented reality (with a virtual reality component for accessibility). However, there are at least two theoretical models for the use of the GLARE development system for hybrid gaming. First, any user interested in coding game mechanics has the ability to do so through GITHUB access. While this is not an ideal response, and while future iterations of GLARE include plans for gaming mechanics, the fact that the project is open source and open access is a great starting point for those who need immediate gaming features.

Second, hybrid games could also rely on real world gaming components. For instance, game creators could create quizzes or puzzles that require users to find content within hotspots. GLARE might point them to a specific location, but they might have to then go further into the hotspot in order to gain access to the clues or answers required to solve the puzzle or move to the next step. Or creators could hide the AR tour on the map but design treasure hunts where users must explore a given environment and look for clues to find hotspots step by step (i.e., the hotspot would appear when they were within range). These activities can be developed for single players or teams, which may collaborate or compete according to experience's goals and objectives.

This gamification of content has shown to lead to better engagement and consumption of learned content [30][38]. It can also significantly improve learner or user motivation [31]. These outcomes, while still theoretical for GLARE-created games, have been shown to be true for other research on gamified experiences in AR and in AR for learning [32] [33].

4.3 Hybrid Learner Production

Aside from these applications and the importance of hybrid storytelling and gaming, GLARE has been designed to work as an accessible tool in which anyone can become an AR developer. This effort is needed due to the lack of user-friendly editors in this regard [21] [22]. But perhaps more importantly, such an effort is needed pedagogically.

When new technologies are developed and integrated, developers often focus on users as consumers. Consumption of technology related material can lead to both positive (and negative) outcomes [1] [34]. But pedagogically, learning occurs when users are active [35]. This can occur during consumption, particularly if users are walking and seeking (i.e., hybrid gaming). Production, however, gives users an opportunity to master the content as they create for others [35]. This change of paradigm can foster autonomy, self-confidence, and motivation [28] [29].

GLARE is well suited to support this trend by allowing learners to play an active role in AR-based storytelling production and development [24]. For instance, students can work with their instructors to design the tour, locate the hotspots, and find and develop materials (from audio to pictures) to include in each. They can draw or photograph images and create musical compositions that are used as the entry point to tours (see Figure 8). This process will allow them to discuss the topics they want to address, which activities they want to present to their users, and the importance of space and location in informing those activities. As such, GLARE can facilitate design thinking, teamwork, and inquiry attitudes toward a variety of foci.

Fig. 8. The opening page of the *Florence Augmented Reality Tour*.

From a technical perspective, the GLARE framework (and related system) asks creators to think about their surroundings and find, develop, and tie content to them in a meaningful way. It allows users to deploy a variety of media to do so, from audio and visuals to text and 3D models. As such, gaining access to the materials to build the story (or even development of those pieces) becomes a key factor in using GLARE. From this perspective, this technology allows producers to focus on the core aspect of hybrid narratives, which is the story and how digital facets can promote it in their association with the real world. Such flexibility can also facilitate customizable narratives where users can design, develop, test, and debrief their own stories by adding content (e.g., new media, new hotspots) iteratively.

4.4 Future Research and Development

These findings suggest five future lines of inquiry that are worth considering. First, AR production requires additional research and support to be properly adopted given its potential. GLARE represents a promising start in terms of features and accessibility, but additional components (e.g., game mechanics, content sharing) should be evaluated as possible next steps for development. Second, more attention is needed to understand how AR creation can be tailored to individual needs and motivations [36] and, therefore, how this process can be personalized according to the reference user audience. Such investigations would shed light on how a) we can build hybrid game interaction models and b) harness the relationship between cognition and game and narrative design in AR.

Third, this article's examples have focused on storytelling and gamification; however, AR technology can also benefit wellbeing and social capital [37]. Such work requires practical and empirical efforts (e.g., how AR production can foster community building and health). Fourth, AR production should be assessed and explored in different learning and social environments to fully analyze its potential, from K-12 education to healthcare settings. This focus would support the design and development of hybrid storytelling models that can be customized for specific objectives and populations. Finally, GLARE production features need to be assessed in terms of usability and efficacy among different audiences (e.g., children, senior citizens) and objectives (e.g., formal educational initiatives, community engagement). Although the first adoptions of this technology have been promising, there is indeed a need for more systematic and rigorous analyses from multiple perspectives.

5 Conclusion

In this article, the development and implementation of the AR editor GLARE have been described to highlight the potential of an accessible AR production in terms of hybrid storytelling and gamification instances. Concrete and theoretical examples were provided to support this claim, and design/implementation insights were suggested for developers and educators. The purpose of this paper was therefore two-

fold: a) promoting the importance of the productive side of AR for hybrid storytelling and gamification with an emphasis on how the development process should be inclusive and accessible to everyone; b) showcasing GLARE as an example of how these efforts can be concretized and inform additional research and applications that can expand the scope and use of this technology.

Acknowledgments. This work was supported by the National Endowment for the Humanities and the grant "Social Engagement in Layers of History: Instant Creation of Universal Access to Humanities Content" (MN-268921-20).

CRediT. Richard Ferdig: Conceptualization, Writing – original draft, Funding acquisition. **Enrico Gandolfi**: Conceptualization, Writing – original draft, Funding acquisition. **Chris Lenart**: Software. **Robert Clements**: Conceptualization, Software, Writing – review and editing, Funding acquisition.

References

1. Ferdig R.E., Baumgartner E., Gandolfi E. (Eds.): Teaching the Game: A collection of syllabi for game design, development, and implementation (Vols. 1-2), ETC Press (2021)
2. Masukawa K.: The origins of board games and ancient game boards. In: Simulation and Gaming in the Network Society, pp. 3--11. Springer https://doi.org/10.1007/978-981-10-0575-6_1 (2016)
3. Nicolopoulou A.: Play, cognitive development, and the social world: Piaget, Vygotsky, and beyond, Human development, 36(1), pp. 1--23 (1993) https://doi.org/10.1159/000277285
4. Burriss K. G., Tsao L. L.: Review of research: How much do we know about the importance of play in child development?, Childhood Education, 78(4), pp. 230—233. https://doi.org/10.1080/00094056.2002.10522188 (2002)
5. Gandolfi E., Ferdig R., Soyturk I.: Exploring the learning potential of online gaming communities: An application of the Game Communities of Inquiry Scale (GCoIS), New Media and Society, https://doi.org/10.1177/14614448211027171 (2021)
6. Gandolfi E., Ferdig R.E., Immel Z. Educational opportunities for augmented reality. In: Second Handbook of Information Technology in Primary and Secondary Education, pp. 967-979. Springer https://doi.org/10.1007/978-3-319-71054-9_112 (2018)
7. Hamari J., Malik A., Koski J., Johri A.: Uses and gratifications of Pokémon Go: why do people play mobile location-based augmented reality games?, International Journal of Human–Computer Interaction, 35(9), pp. 804—819. https://doi.org/10.1080/10447318.2018.1497115 (2019)
8. Vayanou M., Ioannidis Y., Loumos G., Kargas A.: How to play storytelling games with masterpieces: from art galleries to hybrid board games, Journal of Computers in Education, 6(1), 79—116. https://doi.org/10.1007/s40692-018-0124-y (2019)
9. Chou C.Y: Becoming a real-fan or A non-fan for the augmented reality mobile games. In: AMCIS 2020 Proceedings., pp. 1—14. AMCIS (2020)
10. Dorward L. J., Mittermeier J. C., Sandbrook C., Spooner, F.: Pokémon Go: Benefits, costs, and lessons for the conservation movement, Conservation Letters, 10(1), pp. 160—165. https://doi.org/10.1111/conl.12326 (2017)
11. Westin T., Neves J., Mozelius P., Sousa C., Mantovan, L.: Inclusive AR-games for education of deaf children: Challenges and opportunities. In: European Conference on Games Based Learning, pp. 597--604. ECGBL. https://doi.org/10.34190/ecgbl.16.1.588 (2022).

12. Rebollo C., Remolar I., Rossano V., Lanzilotti R.: Multimedia augmented reality game for learning math, Multimedia Tools and Applications, 81(11), pp. 14851—14868. https://doi.org/10.1007/s11042-021-10821-3 (2022)
13. Hong O. A., Abd Halim N. D., Zulkifli N. N., Jumaat N. F., Zaid N. M., Mokhtar M.: Designing Game-Based Learning Kit with Integration of Augmented Reality for Learning Geography, iJIM, 16(02), pp. 1—5. https://doi.org/10.3991/ijim.v16i02.27377 (2022)
14. Wang Y.: Effects of augmented reality game-based learning on students' engagement, International Journal of Science Education, Part B, pp. 1--17 (2022)
15. Deliyannis I., Poulimenou S. M., Kaimara P., Laboura S.: Digital tours: Designing a gamified augmented reality application to encourage gastronomy tourism and local food exploration. In: Cultural Sustainable Tourism, pp. 101-109. Springer. https://doi.org/10.1007/978-3-031-07819-4_9 (2022)
16. Molnár G., Szűts Z., Biró K.: Use of augmented reality in learning, Acta Polytechnica Hungarica, 15(5), 209—222. https://doi.org/10.12700/APH.15.5.2018.5.12 (2018)
17. Devagiri J. S., Paheding S., Niyaz Q., Yang X., Smith, S.: Augmented reality and artificial intelligence in industry: Trends, tools, and future challenges, Expert Systems with Applications, 118002. https://doi.org/10.1016/j.eswa.2022.118002 (2022)
18. Makarov A., https://mobidev.biz/blog/augmented-reality-development-guide
19. Sergey, L., How much will it cost to create a VR app in 2023: 6 steps to your immersive app. Cleveroad Inc. https://www.cleveroad.com/blog/how-much-does-it-cost-to-develop-a-vr-app--discover-in-market-research/
20. Vidal-Balea A., Blanco-Novoa Ó., Fraga-Lamas P., Fernández-Caramés T.M.: Developing the next generation of augmented reality games for pediatric healthcare: an open-source collaborative framework based on arcore for implementing teaching, training and monitoring applications; Sensors, 21(5), 1865. https://doi.org/10.3390/s21051865 (2021)
21. Roberto P., Emanuele F., Primo Z., Adriano M., Jelena L., Marina P.: Design, large-scale usage testing, and important metrics for augmented reality gaming applications, ACM Transactions on Multimedia Computing, Communications, and Applications (TOMM), 15(2), pp. 1—18. https://doi.org/10.1145/3311748 (2019)
22. Zhu L., Cao Q., Cai Y.: Development of augmented reality serious games with a vibrotactile feedback jacket, Virtual Reality & Intelligent Hardware, 2(5), pp. 454--470 https://doi.org/10.1016/j.vrih.2020.05.005 (2020)
23. Gitlin, T. The Sixties: Years of Hope, Days of Rage, Bantam Books (1993)
24. Gandolfi E., Ferdig R.E., Kratcoski A., Blank J. ... Clements R.: GLARE: An open source augmented reality platform for location-based content delivery, International Journal of Virtual and Augmented Reality, 5(1), pp. 1—19. https://doi.org/10.4018/IJVAR.290043 (2021)
25. Raber J., Ferdig R.E., Gandolfi E., Clements R.: An analysis of motivation and situational interest in a location-based augmented reality application, Interaction Design and Architecture(s) Journal – IxD&A, 52, pp. 198—220. https://doi.org/10.55612/s-5002-052-011 (2022)
26. Buchner J., Buntins K., Kerres M.: The impact of augmented reality on cognitive load and performance: A systematic review, Journal of Computer Assisted Learning, 38(1), pp. 285—303. https://doi.org/10.1111/jcal.12617 (2022)
27. Boboc R.G., Duguleană M., Voinea G.D., Postelnicu C.C., Popovici D.M., Carrozzino M.: Mobile augmented reality for cultural heritage: Following the footsteps of Ovid among different locations in Europe, Sustainability, 11(4), 1167. https://doi.org/10.3390/su11041167 (2019)
28. Yanez G.A., Thumlert K., De Castell S., Jenson J.: Pathways to sustainable futures: A "production pedagogy" model for STEM education, Futures, 108, pp. 27—36. https://doi.org/10.1016/j.futures.2019.02.021 (2019)

29. Mitchell C.C., Hessler N.: Cultivating middle school students' literacy learning of story structure through video production, Michigan Reading Journal, 52(3), pp. 1-5 (2020)
30. Nand K., Baghaei N., Casey J., Barmada B., Mehdipour F., Liang H.N.: Engaging children with educational content via Gamification, Smart Learning Environments, 6(1), pp. 1--15 https://doi.org/10.1186/s40561-019-0085-2 (2019)
31. Park S., Kim S.: Is sustainable online learning possible with gamification?—The effect of gamified online learning on student learning, Sustainability, 13(8), 4267. https://doi.org/10.3390/su13084267 (2021)
32. Nguyen D., Meixner G.: Gamified augmented reality training for an assembly task: a study about user engagement. In: 2019 Federated Conference on Computer Science and Information Systems (FedCSIS), pp. 901-904. IEEE. https://doi.org/10.15439/2019F136 (2019)
33. Lampropoulos G., Keramopoulos E., Diamantaras K., Evangelidis, G.: Augmented reality and gamification in education: A systematic literature review of research, applications, and empirical studies, Applied Sciences, 12(13), 6809. https://doi.org/10.3390/app12136809 (2022).
34. Wang J., Stebbins A., Ferdig R.E.: Examining the effects of students' self-efficacy and prior knowledge on learning and visual behavior in a physics game, Computers & Education, 178, 104405. https://doi.org/10.1016/j.compedu.2021.104405 (2022).
35. Ferdig R.E.: Assessing technologies for teaching and learning: Understanding the importance of technological-pedagogical content knowledge, British Journal of Educational Technology, 37(5), pp. 749—760. https://doi.org/10.1111/j.1467-8535.2006.00559.x (2006)
36. Bravo R., Catalan S., Pina J.: Gamification in tourism and hospitality review platforms: How to RAMP up users' motivation to create content, International Journal of Hospitality Management, 99, 103064. https://doi.org/10.1016/j.ijhm.2021.103064 (2021)
37. Laor T.: Running away with the Pokémon GO gang: Three consumption needs, International Journal of Human–Computer Interaction, pp. 1—12. https://doi.org/10.1080/10447318.2021.2002041 (2021)
38. Hou, Huei-Tse, Chung-Sheng Wu, and Chang-Hsin Wu.: Evaluation of a mobile-based scaffolding board game developed by scaffolding-based game editor: analysis of learners' performance, anxiety and behavior patterns, Journal of Computers in Education 10(2), pp. 273--291. https://doi.org/10.1007/s40692-022-00231-1. (2023)
39. Walsh, R.: Emergent narrative in interactive media, Narrative 19.1 pp: 72—85. https://doi.org/10.1353/nar.2011.0006 (2011)