Augmented reality in history education: an immersive storytelling of American colonisation period in the Philippines

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Abstract: History education ordinarily faces a relativist slant, if not by the monotonous nature of the course. Hence, educators are continuously in pursuit for a better teaching strategy to keep the class interesting. The main goal of this study was to 'bring history to life' through a mobile application powered by augmented reality that can provide an immersive storytelling experience on the American Colonisation Period in the Philippines. Outlined as a second quarter lesson in K to 12 Basic Education Curriculum for Social Studies by the Department of Education, the Historic Augmented Reality Application (HARA) depicts the: 1) Battle of Manila Bay; 2) Mock Battle of Manila; 3) First Shot in Philippine-American War. Through a participatory approach, co-designers evaluated HARA in terms of pedagogical value (knowledge acquisition, acceptability, motivation, and attitude), and quality standards (effectiveness, satisfaction, and efficiency) through a usability inspection method. The iterative nature of the project development via a co-design approach with end users revealed early bugs, shortcomings, and possible improvements on the app. The rest is history!

Biographical notes: Manuel B. Garcia is a Professor in Computer Studies at Far Eastern University – Institute of Technology. His research interests include topics that attempt to renovate the landscape of education by challenging the boundaries of technology.

1 Introduction

Trapped by reconfigured pasts that brought manifold truths based from individual interpretations of yesterday, history education ordinarily faces a relativist slant (if not by the monotonous nature of the course) where skepticism concerning the metaphysical and epistemological of causality and truth is ever-present. To overcome these issues, educators are continuously in pursuit for a better teaching strategy to keep class interesting, and portray the best possible version of history. According to Kysela and

Štorková (2015), the deployment of augmented reality (AR) as a medium for teaching history courses underscores the potential of bringing history to life, and offer more interesting information compared to traditional techniques such as historical film viewing and interviews with contemporary witnesses. This AR is defined by Carmigniani and Furht (2011) as a real-time view of physical real-world environments augmented by adding virtual computer-generated information. In the education sector, researchers such as Kesim and Ozarslan (2012), Fernandez (2017) and Kiryakova et al. (2018) have comprehensively studied the potential of AR, and how to use it in transforming education system into 'smart education'. Aside from using AR as a didactic tool in higher education (Rizov and Rizova, 2015), it has also been used and examined in primary education where it received a positive impact on learning experience, motivation, and collaboration among students (Bistaman et al., 2018), and a significant increase in spatial ability and academic achievement scores (Gün and Atasoy, 2017). Consequently, there is now a growing interest among educators in using AR technology as a feature in school curricula.

Figure 1   Flashcard designs of historic events portrayed by HARA (see online version for colours)
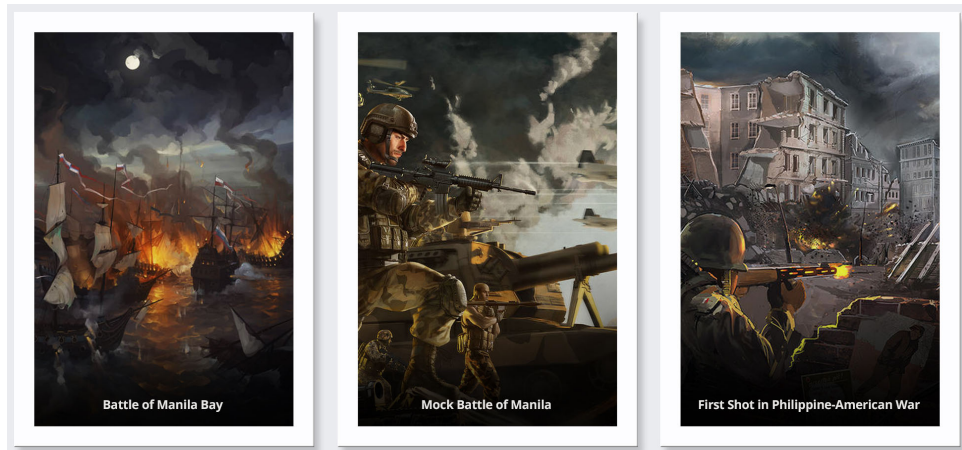
Considering the potential AR technology has in connecting students with new knowledge and stimulating classroom interaction, a variety of AR applications have been already implemented in various courses. In physics, for instance, AR was used by Cai et al. (2013) as a teaching aid for convex imaging experiment where students utilised three markers as a substitute for candle, convex lens, and fluorescent screen. By blending reality with virtuality, the new learning environment stimulated learning interest and encouraged experimentation among physics students. The same outcome emerged from using construct 3D, a three-dimensional geometric construction tool designed for mathematics, where anecdotal evidence publicised an increased attention on experimentation (Kaufmann and Schmalstieg, 2003). AR has also established its reputation in terms of visualisation concepts, for example, visualising analytical instruments (Naese et al., 2019) and abstract concepts like invisible forces in nature (Andersson et al., 2016). In the field of history, AR has been instigated to recreate history by means of embedding the technology on museums and heritage sites (Desai, 2018).

Through handheld devices, people can interact with the past and learn from it. Drawing from the existing AR technologies in education and the suggestion of Kysela and Štorková (2015) to use AR in history education, a historic augmented reality application (HARA) was proposed in this study.

In this paper, the app development, co-design process, and beta testing of a HARA for mobile devices designed to teach history lessons were described. The mobile AR app aims to provide an interactive and immersive storytelling experience on the American Colonisation Period in the Philippines, which is outlined as a second quarter lesson of the academic year on K to 12 Basic Education Curriculum for Social Studies (Araling Panlipunan) on Grade 6 level (Department of Education, 2016). Due to complexity and difficulty of developing AR applications, the covered historical topics for this beta version were limited to the following:

1   Battle of Manila Bay

2   Mock Battle of Manila

3   First Shot in Philippine-American War.

To portray the events of yesterday, 3D models were designed to allow learners to 'see the unseen' – a major advantage of AR that should be leveraged by teachers and app developers when designing a learning experience in augmented environments (Dunleavy, 2014; Yoon and Wang, 2014). As an alternative to AR glasses that are technologically complex and financially challenging to acquire, mobile device was selected as a replacement following the trend towards its ubiquity in school systems (Annetta et al., 2012), and the common school policy known as bring your own device (BYOD) (Miller and Dousay, 2015). Apart from contributing to the existing thread of evidence that proves AR as an effective teaching tool (Fernandez, 2017; Kesim and Ozarslan, 2012; Kiryakova et al., 2018) for both higher education (Rizov and Rizova, 2015) and primary schools (Bistaman et al., 2018; Gün and Atasoy, 2017), this study also intends to challenge the existing literature that AR is not recommended for grade levels (Miller and Dousay, 2015).

This study therefore set three objectives to achieve the research aims:

•   Design and integrate three-dimensional objects into animated scenes portraying historic events of the American Colonisation Period in the Philippines.

•   Develop a mobile AR application designed for history education using a collaborative approach through a co-design process with teachers and students.

•   Perform a beta test with co-designers focusing on perceived change in personal knowledge before and after app usage, perceived impact on acceptability, motivation, and attitude, and usability variables such as effectiveness, satisfaction, and efficiency.

2 Literature review

2.1 AR in education: is it truly for real?

To appreciate the involvement of AR in education, it is important to point out why it was deemed significant by stakeholders in the first place. In a traditional lecture-based education, students are in a passive state and disengaged with academic activities (Ömer, 2012) that usually result to negative experience and unwanted behaviour (Greenwood et al., 2002). As a matter of fact, the manner of knowledge distribution in lecture-based instructions, where knowledge is secluded from context, causes students to raise questions regarding the topic relevance to their lives (Gee, 2009). The absence of effective teaching that is crucial for academic achievements makes the issue more intolerable. Ramsden (1993) has long understood that an effective teaching starts with the learning environment. As stated by Walsh (2011), classroom interaction is a potential area when attempting to improve the learning environment. This is where AR comes in. In a systematic literature review by Jorge et al. (2014) on AR trends in education, the advantage of AR is in the interaction it sparks and its effectiveness in terms of student engagement.

The proliferation of AR in educational settings has likewise brought challenges that need to be disentangled before reaping the benefits of AR technology. Muñoz-Cristóbal et al. (2015) reported the difficulty students experience when using AR although teachers were aided in handling complex educational scenarios in a ubiquitous learning environment. In a sense, while tech-savvy students could easily manipulate and immerse themselves in this uncharted environment, technotards could not. Chang et al. (2014) asserted that usability is a significant technical factor that greatly affects the educational effectiveness. Therefore, usability issues must be addressed before implementing AR-based learning tools particularly those that are reliant on extensive user interaction. Without corrective measures, these usability issues may cause time loss for students because of more attention spent on getting their way around the technology than on learning the concepts that need to be delivered by the tool. In fact, a recent investigation by Gavish et al. (2015) revealed that longer training times were required in the AR training group compared to AR control group. The reported difficulties of using AR learning tool in a school setting were experienced by students upon deployment; therefore, discovering and avoiding these problems and surprises during the early stage of the project development through beta testing is as crucial as the development of the final output.

2.2 Revolutionising history education using AR

History education is perceived as a boring subject in the school (Fielding, 2005), but it is not definitively the fault of teachers nor their teaching style because the most important factor in students' engagement is teaching aids (Al-Shara, 2015). In fact, creative instructional models yield beneficial outcomes in supporting learning environments that can motivate students in generating optimal learning processes. In a mission to remove 'boring' in history education, social media was leveraged by Julien et al. (2018) to deliver an engaging assignment in labour history, and to counter the perception of students that history is boring. By leveraging connectivity, engagement, and accessibility of social media platforms, students exhibited enthusiasm in developing a deeper understanding of

labour history where it was transformed from a collection of dates, facts, and figures into a study of people and their labour movement. Evidently, visualising the past is critical in history education to allow deviation from the traditional memorisation of historical dates, who killed who, and which countries colonialised other countries. And what better way to widen the imagination for visualisation than reliving the past by superimposing historical events onto the real world.

Nevertheless, cognitive overload is prevalent in history education due to the vast historical facts and knowledge that necessitate memorisation and comprehension. This obstacle denotes the educational importance of not overlooking the memorisation skills in learning concepts (Klemm, 2007). In an AR-supported learning environment, cognitive overload is also an issue (Dunleavy et al., 2009) due to the presence of vast materials and complex tasks. Therefore, having multiple cognitive overload issues (course and learning tool) may do more harm than good. A conclusion that may be drawn from this situation is that AR learning tools must be straightforward in terms of content materials (e.g., 3D objects and animated scenes) and user interface design. Another potential problem of AR technology that might be associated with history education is the use of location-based AR application, that is, learners must visit historical places to augment 3D objects (Chiang et al., 2014). A possible alternative to location-based AR application is the use of marker-based AR by using QR codes or flashcards via image recognition. On that way, students do not have to leave school and may relish the usage of AR app anytime, anywhere.

## 2.3   *The value of co-design approach in AR and education*

Teachers and students are undoubtedly central to the teaching-learning process; hence, capturing their teaching and learning experiences is key to innovative learning environments. When designing an educational innovation like AR, design considerations are necessary to meet users' expectations and to address the intended educational need. Alhumaidan et al. (2015) explored a co-design approach with primary school students in designing an AR book to ensure the engagement with and contribution of users. Roschelle and Penuel (2006) described co-design as a team-based process in which users like teachers and students have a role to play in realising the completion of the project. In this kind of approach, better project outcomes could be produced compared to the sole design approach (Trischler et al., 2017). Although students must be trained on how to make valuable feedback and teachers must learn how to be responsive to comments given by students (Bovill, 2014), feedback could highlight the shortcomings of the project (Garcia et al., 2018). Since AR is still an adolescent in the education sphere and an infant in history education, a participatory design could be truly valuable to ensure the coverage of different needs and requirements of teachers and students.

3   HARA – historic augmented reality application

HARA is a mobile-based application that capitalised on AR technology designed to be a supplemental teaching tool in a history curriculum, enabling students to visualise the past through immersive storytelling. The capability of HARA is dependent on image recognition and tracking of pre-defined 2D images (Figure 1) using the inbuilt camera of mobile phones, and then overlays the target media with 3D animated scenes portraying

historic events. To interact with and immerse in the past, flashcards are readily available in the classroom. Given that historians are interpreters of the past where they make sense of given facts from a primary source of evidence, historical narrative was employed as a storytelling technique to portray the story of American Colonisation Period in the Philippines. With this technique, history is in a story-based format to keep the elements of storytelling intact, which is a powerful teaching technique especially for young students (Isik, 2016).

Figure 2 Sample scene breakdown of historical events on American colonisation period for storyboarding
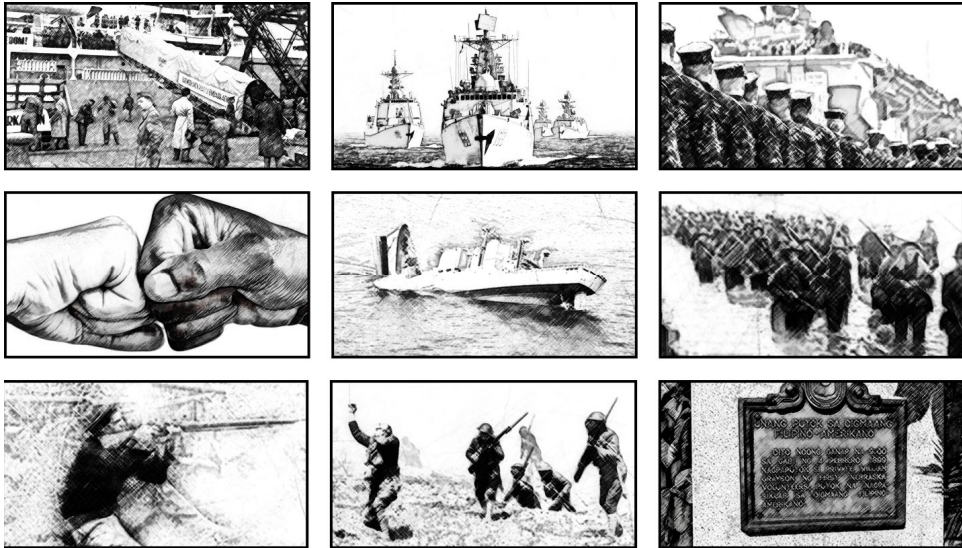
The American Colonisation is a lesson during the second quarter of academic year as outlined by the Department of Education (2016) in their K to 12 Basic Education Curriculum for Social Studies where the medium of instruction is Filipino. The main goal of this lesson is to explain the source of Philippine–American War that lasted from 1899 to 1902 and the impact of American colonialism. This lesson was identified first before diving into the development of AR application to ensure that the project cycle was grounded on the curriculum and pedagogy design of the school, which is critical in designing AR experiences as emerged from the meta-review of Radu (2014). While the lesson includes a comprehensive discussion on the American Colonisation Period, the beta version of HARA was confined with the following historical events:

- Battle of Manila Bay – Spanish colonisation in the Philippines was ended when the US Asiatic Squadron destroyed the Spanish Pacific fleet on May 1, 1898.

- Mock Battle of Manila – Under the negotiation between Admiral George Dewey and Gov. Gen. Fermin Jaudenes, a staged battle was performed on August 13, 1898.

- First Shot in Philippine-American War – On the outskirts of Sampaloc, William Grayson fired the first shot on February 4, 1988 that launched the Philippine American war.
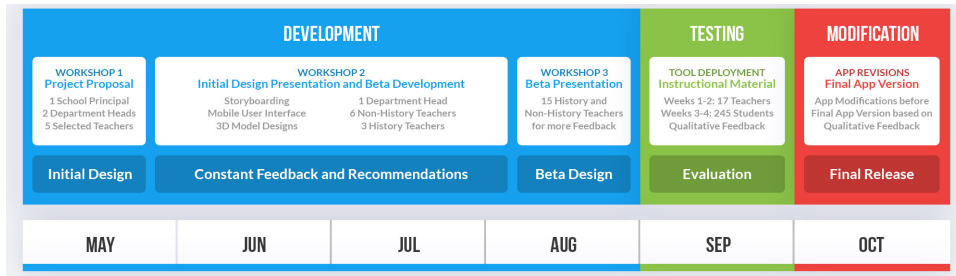
Table 1   Features of the beta version of HARA

Feature	Definition
History	Explore the important historical events of the Philippines using the inbuilt interactive timeline from pre-historic to 21st century.
Characters	Identify Philippine Heroines from various era who only not changed the country but also influenced the world.
Trivia	Read interesting information in a form of trivia presented in a user-friendly mobile interface and organised into different categories.
AR (scan cards)	Provide students with a more immersive experience in learning history through realistic virtual objects controlled in 3D space.
AR tutorial	Learn how to manipulate AR using the app, how image recognition works, and how techy people can change image markers in AR.
Settings	Configure the application in terms of 3D rendering and animation as well as automatic app update notification for future HARA versions.

4   Research methods

In brief, the trial for commencing the trend of using AR in History Education lasted for 24 weeks (see Figure 3), from May to October 2018, through a collaborative and iterative approach using co-design process. With this research approach, end users are treated as part of the mobile app development team and the lifecycle of design process, where their contributions concentrated on their personal experiences, pedagogical practices, perceptions of the subject matter, and learning techniques (Visser et al., 2005). User-centred design methods like this have been a part of a long tradition research where users, be it children (Druin, 2002) or adults (Ellis and Kurniawan, 2000), are involved in some or all stages of design. According to Trischler et al. (2017), the co-design process that involves end users into the development of initial design, like the beta version of HARA, has been shown to produce a better outcome compared to those confined by in-house researchers or experts alone. Such participatory design that actively involves all stakeholders in the project lifecycle enables the exploration of their expectations and needs which then ensure that these requirements will be met when the project is completed.

The first three weeks of the study was allotted for a project proposal, study approval request, and consultation for the feasibility and applicability of developing an AR tool for history education with the assistance of the school principal, department heads, and selected teachers. At this point, end users and target co-designers (history teachers and grade 6 students) were not part of the meeting because it was still a summer vacation and authorisation for study approval was not yet possible. Then, over the course of two quarters (June to October) following the school calendar of the academic year 2018–2019, HARA was developed through a collaborative approach and iterative process using co-design. One month prior to the final version development, co-designers have beta tested HARA in order to determine what can be improved in terms of performance and available features. At this point, teachers were using HARA during their face-to-face meetings with students. All comments and ratings were submitted and collected using in-app feedback tools. Based from co-designers' recommendations, a series of iteration of app modifications were performed during the last month of the study.

Figure 3 Study timeline and procedures of HARA (see online version for colours)

Therefore, the co-design process of this study was composed of phases as follows:

1   Development of the beta version of HARA using a collaborative approach involving history teachers and students and their experience in teaching and learning the lesson, respectively.

2   Beta testing that allowed collaborators to provide their final feedback to the researcher and take suggestions for features and other ideas that may improve the application.

3   App modifications based from the end user feedback prior to the final release of HARA.

4.1   Phase 1: development of the beta version of HARA

It is important to note that an alpha version of HARA (although in concept only), in collaboration with mobile app developers and professors, was already established prior to the beta development of the application. During this stage, informal technical consultations were conducted in order to assess the most suitable platform to develop the app singlehandedly, which libraries and functions can be used to portray historical events using 3D animated scenes, and how to implement image recognition for AR. Based from consultations, Unity emerged as the most suitable platform to use instead of Android Studio that is dedicated for developing Android apps since it can publish mobile applications to over 25 platforms including Android, iOS, Windows, to name a few. Moreover, professors who teach animation and filmmaking suggested that a storyboard could be beneficial during the pre-production stage to convey the flow of animated scenes. Vuforia engine, as suggested by mobile app developers, can be used to arm AR with image recognition using unity. The technical consultation was not reported thoroughly since the focus of this paper is on the co-design with history teachers and students concerning the pedagogical value of the app, and how teachers should deliver the lesson and on what way students will appreciate it more.

During the first phase of the study, three workshops were conducted in collaboration with school personnel. First, the study proposal was presented to the school principal, department heads, and selected teachers to determine if mobile AR application, as a technology-enabled learning tool for history subject, is aligned on their school's vision and mission. Upon their confirmation, the project planning stage was commenced. Three weeks after the first workshop, the output from the planning stage was presented to history teachers using storyboarding for the animated scenes (Figure 2), wireframes for

the mobile user interface design (Figure 3), and 3D models (Figure 4). With these sample designs, co-designers were able to visualise the projected output and comprehend the direction of the project in terms of technical architecture and educational value. Consequently, they were able to contribute several recommendations (even without a working prototype yet) on how to improve the final output in terms of story, branding, app colour schemes, typography and 3D models. After considering the recommendations from co-designers, app features were developed, flashcards were registered for the image recognition, and 3D models were animated to portray events. On the last workshop, the initial release prior to the beta version was presented to history teachers for their final feedback before the app underwent beta testing.

Figure 4   User interface sketch as sample mobile app wireframe design

4.2   Phase 2: beta testing with history teachers and grade 6 students

After several workshops during phase 1, the beta version of HARA was published in both iOS, Android, and Windows mobile operating system. Upon publication, a beta test was conducted with the help of both teachers and students, focusing on their immersive experience while using HARA particularly on knowledge acquisition, acceptability, motivation, and attitude after usage to ensure the app meets not only quality standards but also achieves pedagogical value. Apart from this, the overall appeal of the app and its features were put to test where co-designers provided qualitative feedback. The app usability was also examined using a questionnaire based from the checklist by Guimarães and Martins (2014) designed to evaluate AR applications in terms of heuristic variables such as effectiveness, satisfaction, and efficiency. For the inspection method, heuristics evaluation was employed where co-designers served as the recruited evaluators who are novice to the given AR application. Questions derived from the checklist covered heuristics such as visibility of system status, blending of the app and the real world, user control and freedom, and efficiency of use.

Figure 5 Sample 3D base model: American soldier

Beta testing with co-designers took place over a 1-month period during September 2018 using a paper-based survey in various primary schools. At this time, history teachers have already discussed the lesson about American Colonisation using traditional methods, which established a baseline for comparison in the perspective of students. On the first two weeks of beta testing stage, only teachers were asked to participate. This also gave an extra room for discussing how the app works, and how it can be implemented as a supplemental tool in a classroom setup. Within this timeframe, teachers evaluated the application. The next two weeks were allotted for students' assessment of the app where teachers were free to decide when to introduce and use the technology-enabled learning tool. Afterwards, students rated HARA with the help of teachers. The beta version of the app (apk, api, xap file formats) was uploaded in a private server where teachers and students can download the app. During face-to-face meetings, only the teachers had a device to show and use the application to avoid losing the attention of students. Nonetheless, students were encouraged to download and use the app at home that is why flashcards were given to them after the discussion using AR.

4.3 Phase 3: app modification before public release

In response to the results of beta testing, revisions to the application were made prior to the stable release of the app. Because of the incremental process and iterative nature of the project development, feedback from co-designers were used during the early stage, which saved a lot of time and resources in the long run. Apart from this, suggestions on what features can be added to the next build of the app was also requested from co-designers.

5 Results and discussion

5.1 Phase 1: development of the beta version of HARA

Based from the three workshops conducted during phase 1, the final beta version of HARA was developed according to the initial feedback of co-designers in terms of story,

branding, app colour schemes, typography, and 3D models. The mobile wireframes (Figure 3) were converted into a mockup design (Figure 5) which served as the app design outline during coding and programming activities, and 3D base models (Figure 4) were colourised and texturised (Figure 6). According to teachers, historical accuracy is essential when delivering a lesson in a history subject. Consequently, they recommended several history textbooks that the Department of Education is using as a learning material. In this context, accuracy in portraying what really happened was discussed as well. However, it was agreed that this might be difficult to achieve since there is no paper that has an exact and detailed sequence of events frame by frame. Besides, it is also the reason why a historical narrative was employed as a storytelling technique to allow flexibility in portraying the events. In terms of branding design, co-designers suggested that the identity of the schools in their division should be reflected on the mobile app, if possible. While they had no comment on the app colour schemes, big and bold typography were requested. Lastly, 3D models were requested to be as photorealistic as possible, and accurately portray the clothing during the period, if possible.

Figure 6   Final mobile user interface screen designs: AR (scan card), characters, menu (see online version for colours)
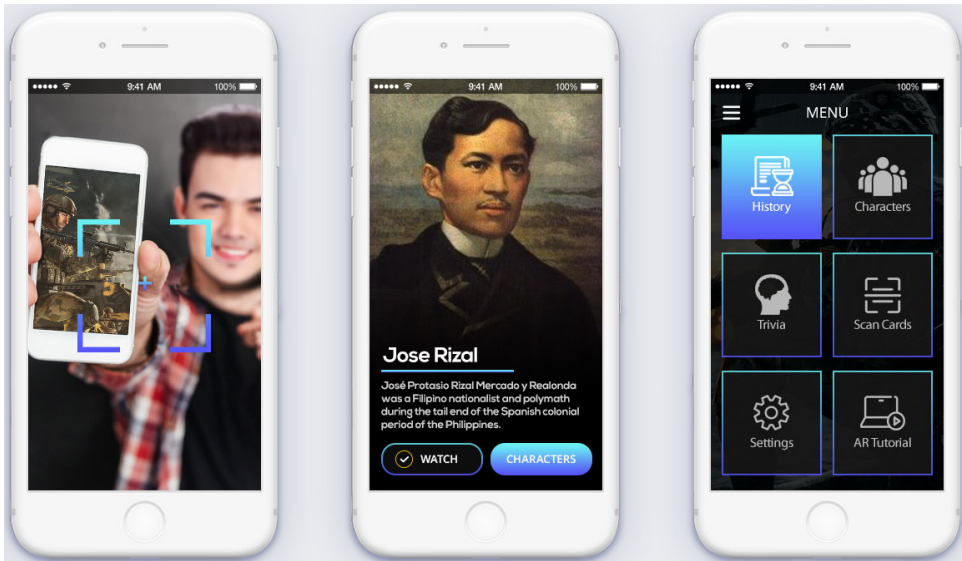
5.2   *Phase 2: beta testing with history teachers and grade 6 students*

Based from the beta testing conducted during phase 2, co-designers evaluated the overall appeal of the app in terms of knowledge acquisition before and after app usage (Table 2), perceived impact on acceptability, motivation, and attitude (Table 3), and the usability based from an AR app evaluation checklist covering heuristic variables such as effectiveness, satisfaction, and efficiency (Table 4). The overall appeal of the app received a high average rating of 4.2 out of 5, where a rating of 1 means 'one of the worst educational apps' and 5 means 'one of the best educational apps'. Most teachers strongly liked the app as an instructional tool (15/17, 88%) and said that they would use the app

again in their lesson on American Colonisation (14/17, 82%). Students, on the other hand, would like to see their teachers use the app in history course (231/245, 94%).

Figure 7 Final 3D rendered model: American soldier (see online version for colours)

5.2.1 *Perceived change in personal knowledge of American colonisation*

One way to grasp the pedagogical value of the app is to determine if there is a perceived change in the personal knowledge of students concerning the American Colonisation period particularly on the historical events portrayed using HARA. A high number of primary students indicated that even without the mobile app, they understood the lesson on American colonisation (192/245, 78%), and showed appreciation on the teaching style (154/245, 63%) and satisfaction on the discussion (139/245, 57%). According to the result, the only drawback of the traditional method (at least based from the response items) was the restriction in visualising the historical events, which was solved after using the app (214/245, 87%). The comparison of the before and after app usage was analysed using t-test to which the result revealed there is no significant difference on all of the response items. While there was a trend toward increased visualisation on the historical events portrayed by the app, this difference was not statistically significant ($P = 0.056$).

Just like the result of recent studies from various researchers who validated whether AR has an impact on student achievement such as Sirakaya and Kilic Cakmak (2018) in computer hardware course, and Erbas and Demirer (2019) in Biology course, the use of AR in history course yielded the same outcome where there was a lack of significant contribution to perceived change in the personal knowledge. Perhaps, teachers were effective on their job in teaching history or perhaps the delivery of the lesson content through virtual objects in a 3D space is not preferred by students because of their respective background (e.g., living conditions, previous experiences, etc.) (Dalim et al., 2017). Although AR has been established to be an effective teaching tool, the use of this technology clearly serves other variables such as motivation (Bistaman et al., 2018), interest (Cai et al., 2017) and engagement (Abdusselam and Karal, 2012). Future researchers, therefore, may conduct a study to determine the factors affecting student's achievement in an AR-supported environment using control and experimental groups.

Table 2   American colonisation knowledge before and after using the app

Response items	Before using app N (%)	After using app N (%)	p-value
I understand the lesson on American Colonisation.	192 (78)	53 (22)	0.051
I appreciate the teaching style in my history class.	154 (63)	91 (37)	0.082
I am satisfied with the discussion on the topic.	139 (57)	106 (43)	0.062
I can visualise the historical events.	31 (13)	214 (87)	0.056

5.2.2   *Perceived impact on acceptability, attitude, and motivation*

Part of evaluating the pedagogical value of the app is to measure the impact of using a mobile AR in the acceptability, attitude, and motivation of co-designers by borrowing some concepts from a theoretical model of AR acceptance (tom Dieck and Jung, 2018). The examination of Table 3 shows that co-designers accepted the pedagogical use of HARA and found it to have a positive effect on their attitude, enjoyment, excitement, and motivation inside the classroom. In a subject that is commonly disliked by students due to unanimous perception that history class is boring (Fielding, 2005), an instructional tool that can foster enjoyment, boost excitement, and increase motivation may turn the tide. Therefore, it is now the responsibility of educators to find an alternative way to develop an engaging learning environment most especially in a subject like History.

Table 3   Agreement with statements regarding app's impact on acceptability, attitude, and motivation

Statement	Agree N (%)	Neutral N (%)	Disagree N (%)
HARA is likely to be useful in the classroom.	153 (58)	39 (15)	70 (27)
HARA is likely to change my attitude on the lesson.	187 (71)	43 (16)	32 (12)
HARA is likely to boost excitement in the classroom	211 (81)	29 (11)	22 (8)
HARA is likely to increase my motivation in the class.	208 (79)	42 (16)	12 (5)
HARA is likely to be part of my favourite educational app.	156 (60)	62 (24)	44 (17)
HARA is likely to foster enjoyment in the classroom.	190 (73)	53 (20)	19 (7)

Just like the findings of the systematic literature review by Jorge et al. (2014) on AR trends in non-history education, the application of AR in history subject is perceived to be useful in delivering a lesson, increase student motivation, change attitude towards the lesson, boost excitement and foster enjoyment in the classroom. As shown in Table 3, Kysela and Štorková (2015) was right to suggest the development of an AR-supported learning environment in history courses because co-designers from this study have a positive attitude towards HARA. As supported by previous studies (Gün and Atasoy, 2017; Naese et al., 2019), the positive attitude of co-designers towards HARA may have a relation to the aforementioned advantages of AR in learning environments and may also stemmed from the increase learning interest and motivation (Jorge et al., 2014). The

interaction features and modern vibe of AR when implemented in educational environment could be the driver of increased motivation (Wei et al., 2015) in addition to attention, confidence, and satisfaction of users that have a significant effect on the motivation factor (Khan et al., 2019). With all the perceived positive benefits of HARA on the learning environment of a history class, co-designers became open to accept the additional AR-based learning tool.

5.2.3 App usability: effectiveness, satisfaction, and efficiency

To date, there has been no mobile application of AR in history courses where 3D animated scenes are used to portray historical events. Therefore, it is vital that the first one should conform to standards in the human-computer interaction field. As such, the app usability was examined using a questionnaire based from the checklist by Guimarães and Martins (2014) designed to evaluate AR applications in terms of heuristic variables such as effectiveness, satisfaction, and efficiency.

Figure 8 Portraying the historic scene of the mock battle of Manila using AR (see online version for colours)

Presented in Table 4 is the result of the application usability inspection where effectiveness, satisfaction, and efficiency of HARA were measured. Co-designers agreed (mean percentage = 82) that the mobile AR designed for history education was effective and successful in producing the intended outcome. Because the portrayal of historical events (Battle of Manila Bay, Mock Battle of Manila, and First Shot in Philippine-American War) were grounded on the outline lesson of the Department of Education (2016), co-designers concluded that HARA achieved its educational goal. Aside from accurate flashcards recognition via Vuforia engine, the interaction during app usage was also clear and intelligible. Unfortunately, there were less co-designers (mean percentage = 51) who were satisfied with HARA. Although the number of virtual objects per scene was proper and that, the freedom to move during interactions was apt; the number of interaction options was not satisfactory. That is, the only interaction available is camera movement since the scenes were pre-rendered already and all they had to do

was watch the animation. Another possible reason was the avoidance of a slower animation and loading time, which was a negative feedback (see Table 5) and caused the app less efficient (mean percentage = 43). Nevertheless, the virtual objects were merged correctly with the real world even though the loading time was not satisfactory.

Table 4   Evaluation of app usability using variables such as effectiveness, satisfaction, and efficiency

Statement	Agree N (%)	Neutral N (%)	Disagree N (%)
Effectiveness			
The application achieved its target educational goal.	231 (88)	26 (10)	5 (2)
The camera can detect the image marker for recognition.	251 (96)	10 (4)	1 (0)
The interaction during app usage is clear and intelligible.	162 (62)	97 (37)	3 (1)
Satisfaction			
The number of virtual objects in the scene is proper.	145 (55)	89 (34)	28 (11)
The number of interaction options is satisfactory.	21 (8)	89 (34)	152 (58)
The freedom to move during interaction is apt.	238 (91)	19 (7)	5 (2)
Efficiency			
The virtual objects are merged correctly with the real world.	153 (58)	79 (30)	30 (11)
The virtual object animation is coherent with the real world.	89 (34)	124 (47)	49 (19)
The loading time of virtual objects is satisfactory.	99 (38)	143 (55)	20 (8)

5.2.4   Overall rate and qualitative feedback of the app

The overall appeal of the app received a high average rating of 4.2 out of 5, where a rating of 1 means 'one of the worst educational apps' and 5 means 'one of the best educational apps'. To put perspective on the overall rating, qualitative feedback was gathered from all of the participants using a mobile-in app feedback tool and divided into positive and negative theme using document analysis as shown on Table 5. The positive reactions were grouped into visual appeal, 3D models, and information while the negative reactions were clustered into animated scenes, loading time, and difficult to scale. Co-designers appreciated the visual interface of the mobile app most especially when their request of big and bold typography was incorporated. Moreover, co-designers also liked the photorealistic 3D models used on the animation. The extra app features of trivia, historical facts, and Philippine heroes, although not necessary nor required on an AR app, also received a positive response. On the other hand, co-designers pointed out the short

runtime and laggy video animation in addition to slow loading time. Consequently, it affected the efficiency of the application (Table 4). While this could be improved by adjusting the number of frames per second (fps), the problem with scalability requires more attention. This has a critical implication for using 3D-based AR in education. Perhaps, this is the reason why 3D animation and AR is not widely used together as an educational tool. Teachers simply do not know how to model and animate 3D objects. As a result, they cannot add their own materials. Therefore, an in-house team of developers or a training for teachers is required when embracing the same AR app.

Table 5   Qualitative feedback of co-designers about the beta version of HARA

Feedback theme	Sample statements
Positive feedback	
Visual appeal	• "The interface is beautiful and the color scheme is modern."
	• "The high quality images add visual aesthetics."
	• "User interface looks professional."
3D Models	• "Soldiers and warships are realistic."
	• "I give the models 5 stars"
	• "The American soldiers look strong and tough"
Information	• "Trivia and history features are very helpful."
	• "Lots of additional information about the history"
	• "I love the character feature and the fun facts"
Negative feedback	
Animated scenes	• "Scenes are too short."
	• "Needs a little bit of exciting war scenes"
	• "Animation is not smooth"
Loading time	• "Loading is slow and takes a lot of time"
	• "Better to preload the app before presenting it in the class."
	• "Waste of time waiting for the animation to finish."
Difficult to scale	• "Not clear on how I can add my own lesson"
	• "I don't know how to create my own 3d models."
	• "I'm not familiar with image recognition, AR, and 3D."

5.3   *Phase 3: app modification before public release*

After the development of beta app version, suggestions were requested from co-designers before releasing the final build of the mobile AR application. The summary of co-designers' feedback and the actions performed from the developer standpoint were presented on Table 6.

Table 6   Summary of feedback and modifications made to HARA

Suggestions from feedback	*Modification(s) made*
Consider adding more history app features like describing the Philippine flag, or maybe listing national symbols[B]	Suggestion was not considered because the goal of the study was an AR learning tool for history lesson and not necessarily a history mobile app.
Cater learners with physical disabilities to ensure that all learners can use the app[C]	Speech recognition was integrated for controlling AR environment (move, rotate, scale, zoom).
Categorise historical facts for better navigation of information[A]	Aside from the interactive timeline, facts were categorised based from their historical themes.
Add Modern-day Filipino heroes from different fields and industries[A]	The heroes of the past and the heroes of today were combined into the character feature.

Notes: [A]Modified prior to the final release, [B]Not modified, [C]Partial modification.

6   Conclusions

In this paper, an educational mobile AR application for history education based from the curriculum outline of the Department of Education on Social Studies was presented. With this application, the findings of the study confirmed that mobile AR is a promising educational tool for a technology-aided history education as evaluated by co-designers of the study. The HARA provided an immersive storytelling experience on the American Colonisation Period in the Philippines by portraying historical events such as battle of manila bay, mock battle of manila, and first shot in Philippine-American war using animated 3D scenes. Instead of teachers narrating a story using excerpts from history books and students trying to imagine these historical events, HARA delivers a consistent and visual storytelling platform for simulation and dramatisation which revolutionise how history is experienced in the classroom.

In essence, HARA is the first mobile AR app that implemented animated scenes with photorealistic 3D models for portraying the events on a subject lesson, and perhaps the first mobile AR app with such features in history education. By infusing HARA in class discussion, co-designers were motivated and had a positive attitude towards the history subject that is perceived as boring by others; hence, the acceptance of HARA for educational environments by co-designers. However, there was no perceived change in personal knowledge of American colonisation. As such, educational leaders are advised to define their goal first before diving into the development and implementation of a mobile AR app because it is daunting, complex, and expensive to develop. Furthermore, teachers have to learn how to design 3D models and animate them in order to add or extend the narrative scenes, not to mention the collective skills needed such as creativity, design conceptualisation, scriptwriting, storytelling, pedagogy design, and technology expertise. This kind of instructional tool requires a team of developers for both content and technical aspects. For this reason, the story was restricted to only three events. Moreover, the study was limited to finding out the potential of AR in history education and co-design approach.

Although mobile AR applications applied on education as a teaching and learning tool do exist, very few have involved co-designing with key stakeholders. In a mobile application development as complex as HARA, the collaborative approach through co-design process provided a significant contribution all throughout the project life cycle.

In doing a collaborative approach, it is essential that sample designs of storyboard, app wireframes, and 3D models be presented to co-designers in order to give them a sense of the project development goal. Without this, co-designers are restricted and not effectively capable of superimposing their teaching and learning experiences on the AR app, which are core in the pedagogy design of HARA. Therefore, an implication of this study lies on providing a new direction for the development of technology-aided tool where users are part of the development team. With students and teachers on the team, the development of such complex project became easier where tasks are accomplished beforehand. Nevertheless, much work remains to be done. HARA only covered the visual storytelling of American colonisation period and there are still substantial major historical events to cover (e.g., Fall of Bataan, Fall of Corregidor, and Death March). Moreover, an avenue of research to cover for future works is the measurement of the amount of learning a student has acquired in an AR-enabled classroom using pre- and post-test model. In conclusion, educational leaders should consider possible ways of infusing HARA with the current history classes, or at least any other established AR-based educational tool. Teachers and students accepted the transformation of traditional discussion setting to an augmented learning environment where the process of learning transfer can be highly motivating and enjoyable.

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