Developing an Educational Augmented Reality Game on the Battle of Mactan Using the Intel Perceptual Computing Kit

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ABSTRACT

The purpose of this study is to produce an educational augmented reality game for elementary students taking up Philippine history in their *Araling Panlipunan* class. The product aims to address the lack of educational software on Philippine-specific topics by making use of the advantages offered by augmented reality. To achieve this goal, the research group developed an educational game on the Battle of Mactan using the Unity game engine in conjunction with the Intel Perceptual Computing Kit. Users play as a contestant in a game show called *Zubu: Battle of Mactan*, competing in a quiz show with AI opponents and playing mini games to learn about the historical battle. Information was organized into three segments: people, events, and culture. Augmented reality features such as gesture recognition and hand tracking were used to facilitate the controls of the game, alongside traditional keyboard and mouse input.

The game showed promising short-term results through the demonstrated improvement between pre-game and post-game test scores of the students. The game may prove to be a helpful tool in learning but may still need further development in order to fully maximize its potential as an aid in teaching.

Keywords

Educational game, Augmented Reality, Intel Perceptual Computing Kit, Unity, Philippine History, Battle of Mactan

1. INTRODUCTION

The Department of Education (DepEd), along with United Nations Educational, Scientific, and Cultural Organization (UNESCO), has pushed for the integration of information and communications technology (ICT) in education. This initiative aims to achieve innovative teaching and learning processes and better school management [3].

One of the benefits of ICT integration, due to its interactive and multimedia features, is the potential to engage and spark the interest of students. McMullan [14] also demonstrates the benefits of ICT through an example in the form of Karen, a student, by showing how ICT has helped facilitate key curricular processes that she used in making her presentation, and how it supported different learning styles, such as working individually or with a group.

ICT in education has been previously initiated by the Philippine Government in accordance with the United Nations' Millennium Development Goals and Education For All initiatives. However, according to DepEd, "ICT integration remains a large task." Aside from the lack of basic computer literacy and an insufficient number of computers, schools are lacking educational software.

Some Philippine history content exists online, such as jakenpoy.com, which features games on the topic. However, augmented reality (AR) applications on the subject are non-existent. The research group aims to develop an augmented reality game using the Intel Perceptual Computing Kit in order to make use of certain advantages of augmented reality that are not present in regular games. Billinghurst mentions some characteristics that are unique to educational augmented reality applications, such as the seamless interaction between real and virtual environments, a tangible interface for object manipulation, and the ability to transition smoothly between reality and virtuality [1]. These characteristics promote an increased degree of interaction with the material and, in the case of group tasks, among the students' own peers. With these advantages in mind, the researchers hope to provide an enhanced learning experience.

In order to measure the application's effectiveness as an educational tool, the researchers will test the game on a sample of their target audience. Learning gains will be measured through diagnostic and comprehension tests.

2. REVIEW OF RELATED LITERATURE

The literature discusses previous work in educational software and augmented reality. It begins by discussing theories on good educational video game design. Next, it reviews studies that examine the potency of games as an instructional medium, along with examples of educational software. It then surveys work in AR and its applications in various fields. The chapter closes by summarizing the historical content of the group's intended application.

2.1 Educational Video Game Design

In designing educational video games, Denis and Jouvelot [2] differentiate between edutainment software and educational games, stating that the main difference between the two is interactivity. Kirriemuir and McFarlane [12] mention that most edutainment software failed to meet expectations due to obstacles such as games being too simplistic, repetitive, patronizing, and having limited and poorly designed tasks. Edutainment calls for linear progression and repetitive exercises to help enforce ideas, while educational games require higher order thinking with content that engages the player on a deeper level. Such content includes elements such as narrative context, a reward system, and interactive cues that provide the player with feedback [5].

These elements tie into the effectiveness of an educational video game. One such element is motivation. Several explanations for the compelling nature of games are offered, such as narrative context, goals and rewards, and the act of playing itself [5]. Dickey [4] states that design strategies that lead to engagement include role-playing, narrative arcs, challenges, interactive

choices, and interaction with other players. On motivation's role in learning, Denis and Jouvelot also state that "Motivation also leads to the activation of efficient cognitive strategies for long-term memory issues like monitoring, elaborating, or organizing information. On the opposite side, resignation and amotivation have negative results on memorization and personal development [2]."

Although several possible reasons are given to explain the appeal of games, a consensus exists that narrative context is an important element of video game design [5]. One study by Waraich [21] claims that games that incorporate a strong narrative make the learning task more meaningful to the learner if it is tightly coupled with the narrative. Fisch [8] also states that using seductive but unrelated narrative details tend to be detrimental because children tend to remember these details over the target material, further supporting the idea that a narrative must be coupled with the material at hand.

Goals and rules are also intimately tied to the narrative context and motivation, drawing players into the game's storyline. A game's system of goals and rules help motivate players of varying skill levels [5]. The other side of goals and rules are interactivity and sensory cues, which give players the illusion of free will despite the limited options. Players are pushed to the edge of their abilities if the game manages to create tension between the player's autonomy and the game's degree of control [5]. Fisch [8] also mentions enhancing learning by providing feedback and hints. These allow users to learn by scaffolding them into successfully answering a problem.

2.2 Video Games as an Educational Tool

Studies into video games as an educational tool were made as a way to improve their potency in delivering content to learners. Kirriemuir and McFarlane [12] state that there are two key themes that are common to the development of games for education, which include the desire to harness their motivational power to "make learning fun", and a belief that "learning through doing" offers a powerful learning tool. They list valuable skills that games may potentially develop, such as strategic thinking, planning, communication, number application, negotiating skills, group decision-making, and data handling.

For "learning through doing", research suggests that the learning processes in playing computer games involve more of participation in practice, rather than the direct acquisition of facts [12]. This manifests in different forms, such as children developing effective use of computer-mediated information resources, games facilitating social interaction among players, which in turn encourages collaboration, and players analyzing games as systems and designed spaces rather than a disjoint set of events. Research into games as a learning tool suggests that games encourage players to learn in ways that are different from those in school. Players, for instance, develop the ability to process information quickly by filtering out irrelevant information, the ability to process parallel streams of information, and a model of doing in order to learn rather than learning in order to do.

Squire [19] also mentions elements of game design that could help make engaging learning environments. One study that he surveys mentions meaningful clear goals, multiple goal structures, and multiple difficulty levels as certain elements that help create enjoyable educational programs. Another study mentions elements such as players having a sense of agency by being in control of their actions, actively pursuing their own goals, being challenged to the optimal extent of their abilities, and being given clear feedback on performance. By incorporating these elements, learners enter a state of "flow" where they are so engaged in activity that their self-consciousness disappears, they are intrinsically motivated in pursuing the activity, and their sense of time becomes distorted. This is in contrast to traditional school environments, where students take on a more passive role.

Furthermore, Squire presents two possible ways for games to be used as educational tools: for drill and practice, and for presenting simulations of real world phenomena. Drill and practice games are used for factual recall, which is in line with the traditional didactic curriculum of schools. On the other hand, simulations model a real world system in order to demonstrate its underlying concepts. Here, learners are able to manipulate variables that are otherwise difficult to alter, view phenomena from different perspectives, observe system behavior over a macroscopic range of time, consider hypothetical scenarios, visualize a system in 3D, and compare the simulation itself to their own understanding of the system that the simulation attempts to emulate. With the help of instructors, simulations can catalyze collaboration and reflection among students.

Some applications have already been made to assist in learning. One example of this is Rome Reborn, a virtual reconstruction of Rome in 320 A.D. [6]. The application uses procedural modeling via the CityEngine software to model several buildings in the Rome simulation. There are also educational applications that make use of augmented reality, such as Multimedia Augmented Reality Interface for E-Learning (MARIE) by Liarokapis et al. [13]. MARIE makes use of a lightweight Head Mounted Display (HMD), a camera, and a computer. It is used as an instructional tool for engineering, wherein it superimposes 3D images on the student's workspace. Its main advantage is its low cost and real-time augmented presentation, although it still needs improvement in human computer interaction. Billinghurst [1] also mentions MagicBook, where normal books are supplemented by 3D models of its story elements, which are made visible through a handheld augmented reality display.

Egenfeldt-Nielsen [7] does mention, however, that using video games as an educational tool does have certain barriers. There are constraints within an educational setting, such as short lessons, physical space, variations in competence among students, installation, costs, and teacher preparation time. Some students and teachers also approach the educational use of video games with skepticism. In his overview of studies on the effectiveness of video games, the general consensus is that learning outcome is promising, but some skepticism is called for because of flaws in methodology, such as a lack of control groups, researcher bias, weak assessment tests, short exposure time, and a lack of debriefing. Comparisons with other teaching methods are also few. Thus, although it can be said that video games facilitate learning, there is little evidence to suggest that video games are a viable substitute for other teaching methods.

2.3 Previous Work in Augmented Reality

In Van Krevelen and Poelman's [20] study, they discuss the technologies used to implement AR. For displays, those that involve sight, sound, and touch are mostly used. For visual displays, there are video see-throughs (virtual elements are overlaid on a video feed), optical see-throughs (virtual elements are overlaid by mirrors or lenses), and projective displays (virtual elements are overlaid on the objects themselves). Displays can be head-worn, hand-held, and spatial. Tracking sensors are used to sense the user and his or her environment, which in turn allows

the application to integrate the virtual objects in reality. For user interfaces, the traditional WIMP (windows, icons, menus, and pointing) UI paradigm does not apply well to augmented reality systems. For systems that do use a WIMP interface, tangible interfaces such as mobile trackballs, paddles, and wands are used. There are also haptic user interfaces, visual UI and gesture recognition, gaze tracking, aural UI and speech recognition, text input, and context awareness, features which allow the system to dynamically adjust the interface based on the user's position.

Van Krevelen and Poelman [20] also survey the various fields that make use of AR, which include personal information systems for general consumers, personal assistance and advertisement, navigation, touring, industrial and military applications, designing, assembly, maintenance, combat simulation, medical applications, entertainment (such as games and sports broadcasting), office, collaboration, and education.

Billinghurst [1] mentions particular characteristics of augmented reality that could benefit educational applications, which are seamless interaction among participants, a tangible interface metaphor, and transitional interfaces. He states that in a classroom setting, students work better when focusing on a common workspace. This allows them to share communication cues, such as gaze, gesture, and nonverbal behavior. A tangible interface allows users to interact with software using physical objects, which support collaboration through their use as semantic representations and their ability to help focus attention. Transitional interfaces allow the user to experience the full reality-virtuality spectrum, letting them immerse themselves in the content at a deeper level with the help of virtual artifacts while also interacting with real world elements.

Although augmented reality has several actual and potential uses, Van Krevelen and Poelman [20] also mention some of its drawbacks. Its technological demands are greater than those of virtual environments or VR, which is why the field of AR took longer to mature than VR. There are also technical challenges in AR implementation, such as binocular view, high resolution, color depth, luminance, contrast, field of view, and focus depth. Other limitations and challenges in implementation include portability and outdoor use, tracking and calibration, depth perception, stimuli overload, and social acceptance.

For the Intel Perceptual Computing Kit, its product brief [17] states that it supports speech recognition, facial analysis, close-range depth tracking, and augmented reality. Speech recognition is achieved via an algorithm that interprets speech, which is then passes to the application. Facial analysis supports facial recognition, facial tracking, gender and age determination, and attribution detection, which allows the detection of facial gestures such as smiling. Close-range depth tracking is the recognition and tracking of hand poses and gestures. For the kit's augmented reality features, input from the camera is combined with other graphics elements, putting the kit's virtual display under the video see-through category mentioned earlier.

2.4 16th Century Philippine Society

In Scott's [18] detailing of Philippine society in the 16th century, he describes aspects such as the Filipinos' physical appearance, weapons and warfare, and forms of entertainment.

Early Filipinos in the Visayas area had decorative dentistry, coloring their teeth black by chewing *anipay* root or *tapul*, a tar based coating. Alternately, they colored their teeth red by chewing on red ant eggs and *kaso* flowers. For clothing, they wore items such as the *malong*, *bahag*, *pudong* (turban), and *potlong* or *saplung* (headcloth). They had pierced ears, and jewelry was part of their normal attire, which includes *panika* (rings), *dalin-dalin* (simple loops), *kayong-kayong* (pendant hanging from earring), *sangi*, various necklaces, *binukaw* (bracelets of gold and silver, *onat* vines and rattan *pikit*), and *kamagi* (gold chain of interlocked rings). They had various tattoos, such as the *labid* (leg to waist), *dubdub* (chest to throat), *bangut* (face), *daya daya* (arms), and *hinawak* (below the waist). They usually had long hair, and hairstyles could go in and out of fashion quickly.

They had a variety of weapons as well. For swords and daggers, they had the *baladaw*, *kris*, and *kampilan*. They used spears such as the *bankaw*, *songil*, *piniskan*, *liparak*, *lanab*, and *binusloran*. They used projectile weapons like the *sugod* (bamboo spears), *busog* and *odyong* or *pana* (bow and arrow), and *sumpit* (blowgun). Their defensive arms include the *barote* (thick braided abaca or bark cords), *pakil* and *batung-batung* (breastplates and backplates), *moriones* (helmets), and *kalasag* (shields). Their general term for warfare was *gubat*, and their strategy and tactics include *angat* (provoking the enemy), *naga kamatayan* (fight to death), *mangin matay* (desperate man determined to die on the field of battle), *balita* (bad news of death), and *hugyak* or *ugak* (shouts or chants of returning victors).

2.5 The Battle of Mactan

In Pigafetta's [16] account, he narrates from when they arrived at the port of Zubu, the first baptism in the Philippines, until Magellan's death. He also included descriptions of the appearance and customs of the Filipinos in Zubu.

They arrived at the port of Zubu (Cebu) on April 7, 1521. As part of their custom to honor the king of the village and as a sign of peace and friendship, they fired all their mortars. This initially scared the people of Zubu. Along with them was an interpreter called Henrich who accompanied a foster-son of their captain-general (Magellan) to meet with the king of Zubu. They initially said that their purpose was to trade.

There was a disagreement regarding payment of Spaniards for docking in Zulu's port since they did not want to pay tribute. This was resolved the next day by performing a blood compact and by assuring that they want to trade. In the following days they started teaching about Christianity, God, and the commandments.

The first baptism in the Philippines occurred on April 14 which involved Raja Humabon, his wife, and 800 others. This ceremony included changing of the native's names to Christian names like renaming Raja Humabon to Don Carlos and his wife to Johanna. They also replaced the native's idols with images of Jesus Christ, Virgin Mary, and the cross.

Pigafetta's account also included a description about trade and the wooden scales the natives used for trade, ceremonies for preparing the swine for consumption, the ceremony when a chief dies, how houses that were made of wood and bamboo looked, what the youth did, and animals and creatures he had seen.

Zula and Lapulapu were the two chiefs of the village of Matan (Mactan). Zula promised to obey the Spaniards but Lapulapu refused, so he asked help from the Spaniards to fight Lapulapu. The battle of Mactan was fought on April 27, 1521. When they arrived at before dawn, they first sent a message to serve as a warning for Lapulapu. The battle commenced at morning. Pigafetta wrote that about 49 men crossed the water to attack while the natives had more than a thousand five hundred men. He mentioned that they were divided into musketeers and

crossbowmen. According to him, the natives would not stop attacking, hurling bamboo spears, and shooting objects such as arrows, wooden stakes hardened with fire, rocks, and mud. Spaniards burned about twenty to thirty houses. The natives only shot at their legs since those had no protective armor.

The Spaniards began to fall back when Magellan was hit by a poisoned arrow. Natives continued to attack them as they were retreating. The natives turned their attack to the captain when they recognized him. Pigafetta recounted the death of Magellan at the hands of the natives, saying "An Indian hurled a bamboo spear into the captain's face, but the latter immediately killed him with his lance, which he left in the Indian's body."

2.6 Summary

In developing educational software, factors such as motivation, narrative context, goals and rules, and interactivity and sensory cues affect how effective a game is as an educational tool. Billinghurst also suggests reaping benefits offered by AR in developing educational software, which include a tangible interface, seamless interaction, and transitional interfaces. The concepts presented in these studies can potentially serve as a foundation for the design of the application.

Van Krevelen and Poelman's survey of AR showed hardware devices used to implement AR applications that are present in different fields. For education, example applications include MARIE and MagicBook. A non-AR example is Rome Reborn, which teaches about history. Although there exist both AR and non-AR educational applications, software on Philippine history is scarce. Using historical sources such as Scott and Pigafetta, the research group hopes to create software on Philippine history that takes advantage of AR features.

While previous augmented reality programs such as MARIE and MagicBook present information through more novel or tangible interfaces in order to enhance traditional learning methods or take advantage of AR's inherent benefits, their degree of interactivity was limited. The researchers hope to incorporate the benefits of AR and the interactivity of video games in order to produce educational material on *Araling Panlipunan*.

3. METHODOLOGY

The methodology section describes the steps taken to create the game's mechanics and historical content.

3.1 Historical Data Gathering

In order to gather the historically accurate data necessary for the creation of content for a historical game, the researchers referred to both primary and secondary resources about pre-colonial Philippines. Such sources include William Scott's collection of essays on Philippine history and Antonio Pigafetta's account of their expedition to find the spice island, Moluccas, wherein they stumbled upon the Philippines.

3.2 The MDA Framework

Design of the proposed game will follow the MDA (Mechanics, Dynamics, and Aesthetics) framework detailed by Hunicke, LeBlanc, and Zubek [10]. In this framework, the consumption of games is broken down into three components: mechanics, dynamics, and aesthetics. Mechanics describes the game's components in terms of data representation and algorithms. Dynamics describes the behavior of mechanics when interacting with player inputs and each other's outputs. Aesthetics describes the desirable emotional responses evoked in the player when interacting with the game.

Each component can be thought of as a separate but causally linked aspect of the game. That is, one change in a component will propagate to the others as well. Another thing to consider is that there are two perspectives: the designer's and the player's. For the designer, mechanics give rise to dynamics, which in turn produces an aesthetic experience for the player. Thus, designers are more focused on mechanics. On the other hand, the player focuses on the aesthetic experience, which is grounded on the dynamics and mechanics of the game. It is important to consider the player's perspective in designing a game, which encourages an experience-driven design approach.

In elaborating on aesthetics, Hunicke, LeBlanc, and Zubek form a taxonomy that describes the different ways in which a game could be fun. Examples include fantasy (games as make-believe), expression (games as self-discovery), and discovery (games as uncharted territory). In Pereira and Roque's [15] proposed model centered on player participation, six perspectives are noted, which include playfulness, challenge, embodiment, sensemaking, sensoriality, and sociability. Like the aesthetic categories listed in the MDA framework, the six perspectives pertain to the players' experience. The previously listed categories serve as a basis for desired goals in gameplay, and they explain how each game appeals to a different variety of players.

The aesthetic taxonomy described by the framework can help define the dynamic models of the game. These dynamic models help predict results in game behavior and avoid design flaws that may reduce the game's aesthetic impact.

The dynamics of a game are grounded by its mechanics. Mechanics include basic actions that can be taken by the player and elements that define these actions, which may give rise to strategies and rules that compensate for the imbalances that a combination of mechanics may cause.

Part of the MDA framework is tuning the game in order to balance it. This is an iterative process that gradually improves on gameplay. The aesthetic vocabulary and dynamic models serve as a reference for tuning by articulating design goals and flaws.

3.3 Using Software Development Kits and Development Platforms

The Intel Perceptual Computing Kit was used by the researchers for the augmented reality aspects of the game. For the game's development environment, the researchers used Unity, which can support the Intel Perceptual Computing Kit's features.

According to the Intel Perceptual Computing Kit's manual [11], "the Intel Perceptual Computing SDK is a library of pattern detection and recognition algorithm implementations exposed through standardized interfaces." These interfaces are in the C++ programming language, and they define the functionality of core frameworks, I/O modules, and algorithm modules.

The SDK programming model follows four general steps: session creation, module creation, module operation, and close down. The first step to creating an application is to create a session instance, which holds all algorithm modules. The next step is to create instances of algorithm and I/O module, which are then used by the application to invoke certain functionalities. Finally, when the application is closed, it releases all created instances.

The SDK's modules include finger tracking and gesture recognition, face tracking and recognition, and voice recognition and synthesis. The finger tracking and gesture recognition module allows the application to detect poses (static hand and finger positions) and gestures (sets of changing poses or patterns) via the camera. The face tracking module allows face detection (general detection of human faces), landmark detection (recognition of specific facial features), face recognition (recognition of a face as belonging to a specific person in a database), and face attribute detection (analysis of general physical attributes such as age group, gender, and expression). For voice recognition, features such as voice command and control, dictation, and text to speech. In command and control, the application responds to voiced commands based on a predefined list of context words. Dictation returns the most likely dictated sentence based on speech input.

The SDK also supports certain frameworks and game engines. These include the Processing framework, the openFrameworks toolkit, and the Unity game engine.

Unity is a game development environment that is available in a free version and a professional version. The game output of this research was developed using Unity Pro, the professional version of Unity 3D. The researchers chose to develop using Unity Pro because of its availability and ease of access, as well as its support for plugins, which is needed in order to access the Intel Perceptual Computing Kit's features.

3.4 Measuring Effectiveness

In measuring the effectiveness of the application, a pre-test, post-test, and a feedback questionnaire were administered to gauge the students' opinions on the software they used. Students were asked their opinions about the game, ranging from user-friendliness issues to the educational effectiveness of the game. This allowed the researchers to determine which aspects of the software should be improved or given more focus.

Because knowledge gained from previous AP classes may skew the results, a sample of Grade 6 students was gathered for the study instead of Grade 7. In coordination with Ateneo de Manila Grade School, four students were randomly chosen to participate in this evaluation.

The testing procedure has three main phases:

1. Pre-game: Consists of the participant answering the participant information survey and the pre-test.

2. Game: Consists of actual gameplay involving the developed software.

3. Post-game: Consists of the participant answering the post-test and the evaluation form.

The participants first accomplished a profile questionnaire before the game phase and a debriefing questionnaire afterwards. The debriefing questionnaire contained questions that request the participants to rate certain aspects of the software, such as game controls.

Following the studies mentioned in Whitton's research [21], the testing phase consists of the answering the pre-test, using the software, and a post-test. A standard written pre-test and post-test was administered to all the participants. Both tests contained the same questions to ensure the same level of difficulty. The order of questions and choices differed. These questions are based on the quizzes or tasks of all the modules of the game.

A multiple choice format was used in the tests, just like the format of the quiz in the software. Each question also provided four choices. There was also a section with identification questions. There were no true or false questions because students have a 50% chance of getting a correct answer through guessing, thus reducing its effectiveness for measuring learning [9]. The tests were composed of ten multiple choice questions and five identification questions.

The pre-test was administered immediately before the student tested the game, while the post-test was administered immediately after. For each of the two tests, each participant was given around 20-25 minutes to answer, and 45 minutes to play the game in order to ensure that all participants had enough time to explore each module. Around 3 minutes was also used to brief the participants on the controls of the game after answering the pre-test. The research group stayed in the same room as the students but kept distance unless they asked for support or seemed to struggle with the controls.

4. DEVELOPMENT AND RESULTS

The researchers worked on an educational game that has a quiz show format, wherein the player solves the problems using the Perceptual Computing SDK's features, such as gesture recognition. The type of game was chosen and developed in order to provide the user with a fun and educational experience. The game was retooled from an adventure game to a quiz show due to time and resource constraints on the research group's part.

4.1 Overview of Development

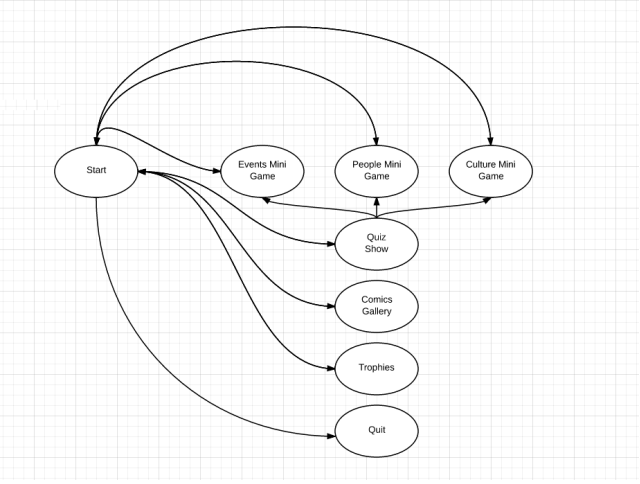

Figure 1. Overview of the game's flow

In developing the game's educational content, important facts were chosen regarding the Battle of Mactan and were grouped together into three categories to create the three modules for the game. The important information was filtered based on the researchers' previous experiences in elementary history classes. The questions were formulated in order to improve the player's recollection and retention of the material.

With respect to the MDA framework, the researchers decided on creating an aesthetic experience that captures the feeling of being in a televised quiz show. The now-defunct Nickoledeon game show *Legends of the Hidden Temple* served as the primary inspiration for the game's feel, making use of storytelling

followed by a question and answer round and follow-up mini games that corresponded to the tasks that players in the TV show must accomplish. The researchers aimed to foster a sense of challenge and fantasy to the players of the game through the game's structure and stylistic presentation. The aesthetics of the game are presented to the player through the dynamics. A sense of challenge was incorporated by having the player compete against AI opponents in the question and answer round, who have randomized response times that fall within the range of a few seconds and moderate accuracy rates. Although the players were presented with a sense of challenge, the researchers noted that the main goal is for the user to learn, which led to the decision that the AI opponents shouldn't be too difficult to beat if the player paid enough attention to the comics. The mini games do not feature opponents, but nonetheless challenge players to reach a certain score or limit their mistakes in order to win the round. A sense of fantasy or immersion was intended by modeling the game's mechanics after television quiz shows as best as possible within the researchers' resource constraints. The incorporation of augmented reality elements also aimed to enhance the player's immersion. The mechanics of the game are discussed in detail in the following paragraphs.

The game, *Zubu: Battle of Mactan*, covers events in the Battle of Mactan and some 16th century Philippine culture. The game consists of a quiz show round, with each of the three modules having a unique final round that the player unlocks after successfully completing the quiz show round. The three modules that the player may choose from are people, events, and culture. The design document of each module contains the questions, related comic strip draft and script, and the mechanics of the final mini game round. The player may also acquire in-game trophies for each round, which can be viewed in the game's Trophies section. The trophies section also functions as a museum of sorts, with each trophy displaying pertinent historical information about

Figure 2. The game's main menu

the object or figure it depicts.

In the quiz show round, the player takes on the role of a contestant in the game show, competing against two AI opponents. Before the game begins, the player is shown a series of comic strips about the topic at hand. The player uses hand swiping gestures from the Perceptual Computing Kit to move across the pages of the comic strips. Once the player is ready, a multiple choice question and answer game begins. The question and four choices will appear onscreen. The player must press the space bar to buzz in, wherein he or she is given three seconds to choose an answer. During this interval, the player may press any of the letters A, B, C, or D on the keyboard to select a choice. If any of the contestants make a mistake, one more chance to "steal" is given to the other two contestants. In order to win and advance to the next round, a contestant must either garner ten points first or have the most points when all the questions have been exhausted. In the case of a tie, the player does not advance to the next round; he or she must strictly have more points than both opponents.

Figure 3. The quiz show round

In the events module final round, the player is shown six objects onscreen that represent certain events in the Battle of Mactan, along with six corresponding descriptors. Using the gesture camera, the player must "grab" each object by moving a pointer to the object by moving his or her hand across the camera and closing his or her fist. After doing so, the player must drag the object to its appropriate descriptor and release it by opening his or her palm. If the player makes a correct move, the object fixes itself near the descriptor and becomes unmovable. If the player releases the object on an incorrect descriptor or anywhere else on the screen, the object moves back to its original place. The player is allowed one mistake; upon making a second mistake, the round ends and the player may opt to start over. Releasing the object outside any descriptor does not count as a mistake.

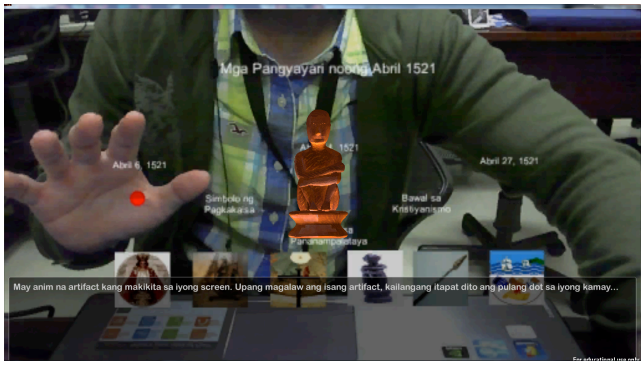

Figure 4. The player plays a matching game by grabbing the objects on the screen

In the people module final round, the player is given certain scenarios that involve two people or parties. The player must determine if the scenario is peaceful or conflicted by flashing certain gestures at the camera. If the scenario is peaceful, the player flashes a V-sign at the camera. Otherwise, the player flashes a thumbs down gesture at the camera. In order to win the round, the player must get at least five correct answers out of seven scenarios.

In the culture module final round, the player is presented snapshots of life in 16th century Philippines. These snapshots

contain inaccuracies, however, wherein certain objects or figures have become absent or are anachronistically replaced with modern items. The player must decide what the correct item or figure should be in the scene by typing in an answer. He or she has two chances to figure out the correct answer. In order to win the round, the player must get at least six correct answers out of ten scenarios.

The game's "trophy room" functions similarly to the final round of the events module. A shelf containing the trophies that the player has won is shown. The player may move his or her hand across the camera and "grab" a trophy by closing his or her fist near it, in a similar manner to how objects are moved in the events module final round. The player may then place the trophy on a pedestal, which causes the game to display some information and trivia regarding that trophy.

Figure 5. The player wins a trophy for each round won, with each trophy displaying historical trivia

4.2 Feedback and Analysis

The game was tested by four sixth grade students. Information gathered from the participant survey form shows that all the students had a grade above 90 in AP/Philippine History. Most of the students consider themselves as having an above average familiarity with Philippine History and Filipino Culture. Most of them are highly interested in the Philippine History Subject and highly fluent in Filipino. Most of them are performing very well overall in school. All of them are very interested in games.

All of them consider visual aids as an important tool in learning and teaching and they learn more when images are involved compared to plain text. They all believe that student participation is important in learning. All of them believe that games can be used as a form of teaching.

All the students study regularly. Their time spent in studying ranges from 1-2 hours to 4 or more hours. Their material for studying includes lecture notes, books from school, online references, other written reference, and educational games.

The students were a mixed group when it comes to gaming habits. One plays daily. Another plays only during specifics days. Another plays only on days when there are no classes. One student almost never plays. The time they spend on playing games ranges from less than an hour to 4 hours on days when they do decide to play.

The students were asked to evaluate the advantages and disadvantages of using games as part of the classroom instruction. Most of them mentioned the fun factor, which they believe might help with the learning process. For the disadvantages, one of the students posed the question of a game's thoroughness or the level of information that a game could give. He also cited the possible impression that it may leave on some students such as having games as a "new teacher". He also questioned the value of games as an independent learning resource, because if a student ever has a question, the game will be unable to directly answer it. Another student posits the possibility that the student might play the game purely for fun or in the wrong way, forgetting about the lesson.

For the feedback questionnaire, students were requested to give their opinion on certain features of the game. All of the students tested strongly agree that the game helped them learn more about the battle of Mactan. Most students strongly agree while one agrees that the game helped them learn more about the culture of early Visayans. Most find the instructions and mechanics easy to understand; however, one student doesn't agree. Most find the game more interesting because of the controls used in it while one doesn't agree. Most strongly agree that the game was innovative while one agrees. Half strongly disagree that the game was confusing, one disagree, and the other is neutral about it. Half strongly agree that the game was engaging, one agrees while another was neutral about it. Most students strongly agree that the overall game play was good while one agrees. All of them enjoyed the game. Two of those students strongly agreed that they enjoyed it. Half strongly disagreed that the game was nothing new, one disagrees, and another was neutral about it. 3 out of 4 students tested strongly agreed to having similar games help them study their lessons in school, the other one was neutral about it.

The students liked the variety of information and thoroughness that the game provides. They also appreciated the use of the gesture camera and the way the information was relayed, which was through a comic book form of storytelling. The students disliked the controls, particularly the ones involving the gesture camera due to unresponsiveness. The length to finish the game also proved to be a problem for the students. The students unanimously said that they would play the game during their free time, mostly because of the knowledge that they could acquire by playing the game. All of them said that they would ask their friends to play the game for various reasons, such as "because they would also learn more which could help them in their studies", "because it is different from the other games" and "because I'm sure they will like the controls of the game."

In improving the game, the students gave their input. Generally, they suggested fixing the gesture camera with regards to its sensitivity to movements. One student suggested having "a summary after each lesson". Another suggested making the controls less fancy in order to accommodate potential players who are not accustomed to the gesture camera.

What I liked the most about the game is/are...	What I liked least about the game is/are...	Would you play this game in your free time? (Yes or no? Why?)	Would you ask your friends to play the game? (Yes or no? Why?)	How do you think we can make the game better?
It is informative and fun	The controls are very hard	Yes so I can learn more	Yes because it is fun and informative	The controls were too fancy and hard. Make it easier so that those who are not used to these kind of games and controls can adjust.
The comics. I learned a lot from it.	-	Yes. Because I will learn more when I play this game	Yes. Because I'm sure that they will like the controls of the game.	By improving the motion camera.
The use of the camera	The camera does not respond sometimes	Yes I would because it is different from the other games I play	Yes I would because it is educational and again it is different from the other games	I think that the camera needs a bit of fixing
That the information was realy detailed- from culture to people and events to results	That the time to take up everything was long proving that games can't be teachers unless there is a vast space of time which is unavailable in our school as we are only allotted 40 minutes per subject, but this could still help in studying.	Yes, because I would not be in a hurry and I will be able to observe more and know/learn more	Yes because they would also learn more which could help them in their studies.	I think the game could be made better if the camera used for control would be more sensitive - sensitive enough to capture the smallest movements and there is a summary after each lesson

Table 1. A summary of student responses to the survey form

When the pre-test and post-test results were compared, all students exhibited an increase in their test scores after playing the game. The greatest change is from having a score of 6 to 13 and the slightest change is from having a score of 10 to 13. The questions in the test were composed of information that was both old and new to the students. All of the material in the test was covered by the game through the quiz show, mini-games, and comics sections. By correctly answering questions in the post-test that they previously got wrong in the pre-test, the students demonstrated the acquisition of new information by playing the game.

The game proved to be a tool for learning and tested well with the students. The Intel Perceptual Computing SDK seemed to have a potential for added experience in learning. However, certain aspects of the gesture camera needed improvement, such as its response to gestures or movements. A familiarity with the gadget is also needed as a student commented that "The controls were too fancy and hard. Make it easier so that those who are not used to these kinds of games and controls can adjust." We speculate that using the gesture camera in a classroom setting will also require a certain learning curve.

5. CONCLUSION

The Intel Perceptual Computing Kit can be used to develop an augmented reality educational game by integrating its features in the gameplay. Finger tracking and gesture recognition were two features used in the controls of the game. Gesture recognition can recognize SDK-defined gestures such as poses like a closed fist or a peace sign and actions like a swiping gesture. This feature was used during the story telling part of the game and the final round of the people module. Finger tracking was used in the final round of the events module and the trophy room of the game.

As to whether augmented reality added any value to the experience of the educational game, one of the student testers showed some appreciation for the use of the perceptual computing kit's gesture camera. However, all the testers criticized certain aspects of its use, such as its responsiveness and its sensitivity. The practical value of augmented reality over traditional interfaces could be explored in a future study that makes use of and compares both types of interfaces.

The game showed promising results with the improvement of test scores of the students. In general, use of the Intel Perceptual Computing Kit's features in the game may prove to be a helpful tool in learning. However, some of the SDK's features may still need some improvement or refinement when it comes to implementation, which is beyond the scope of this study. Another possible improvement is the actual usage of the kit's features in an educational game, wherein other unused features such as facial recognition may be deployed, and other ways of using the kit's features may be conceived as possible alternatives to the methods that were used in the game.

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