Co-Creativity Fusions in Interdisciplinary Augmented Reality Game Developments

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ABSTRACT

This paper recognizes and reflects upon the important co-creativity roles and intimacies that arts students may play in increasingly interdisciplinary environments where research and design potentials of evolving new media technologies are being explored. We report a real-world case study where two students played the dedicated artists' roles of art and game design developments while working with staff researchers from technical, design and social science (education) backgrounds to develop an outdoor location-based handheld augmented reality game project. The paper relates how a clearer understanding of such didactic situations can empower and invoke co-evolutions of both art and technology.

KEYWORDS: Interdisciplinary Research, Augmented Reality, Human-Computer Interaction, Games.

INDEX TERMS: D.2.10 [Software]: Design — Methodologies; H.5.1. [INFORMATION INTERFACES AND PRESENTATION]: Multimedia Information Systems – Artificial, augmented, and virtual realities; K.8.0 [PERSONAL COMPUTING]: General – Games

1 INTRODUCTION

1.1 Practitioners and Students of Creative Arts in Interdisciplinary New Media Research

1.1.1 The Practice

There is a fundamental difference in the creation of art for 'new media' as compared to older or traditional forms of (visual) art as it requires a collaborative infrastructure to produce and regularly involves (in academia) a network of artists, technologies, research collaborators, funding institutions, curators and exhibiting venues/structures [1]. [2] termed this as 'software-dependent artwork' which interdisciplinary projects offer as co-creation opportunities for software developers and artists to work closely together. The notion of artists and technologists working together is however not new ([2-4]) even in the Augmented Reality (AR) technology space ([5]) and empirical models to scientifically exemplify the co-creativity processes that exist between such relationships have been previously proposed (i.e. [6] for mixed media, and [7] for interactive art). Technology researchers when working with collaborating artists tend to attribute that artists would consider their (artists') own participation to be a form of *practice-based research* ([8,4]), one that is often heavily influenced by Schön's *'reflective'* concept of the self ([9]), according to [3]. Artists on the other hand, when seeing technology as an artistic medium, draw creative ideas by using an in-depth knowledge of how technologies operate through experimentations [5].

1.1.2 Maintaining an Equilibrium

Apart from the promised synergies of innovations that such interplaying arrangements are said to bring, 'sparks' (friction) may also occur in artist-technologist collaborations ([10]) and not function smoothly due to one or many of the following reasons - 1) *diverse disciplines of participating collaborators*, 2) *inexplicit system specifications in artwork requirements that are subject to changes even during late stages of a project*, and 3) *collaborations between artists and technologists are often driven by creativity and innovation rather than by a specific functional purpose* [2], etc. In a review of practice-led research, [8] identified that possible barriers of languages may exist between academics and practitioners. A bottom line thus lies in the relationships between individuals, ideas, actions and productions as *communication* (bearing a feedback-loop structure of continuous 'form and re-form' [11]), and *mediation* ([10]) processes of individual participants during an actual collaboration that is assimilated over various periods of time and within diverse socio-political situations [11,6].

In the view that theory and practice can each lead to developments of the other ([7]), a collaboration process that forces us to reposition our thinking can lead to new insights (creative and novel uses) for arts in the technology space [4], produce positive outcomes of integrated cross-disciplined knowledge [3], and identifies requirements for support environments [11,6]. It is held in the common belief by the stakeholders involved (collaborators from different backgrounds) that **access**, **knowledge** and **understanding** of the capacities of the technology and its associated constraints (direct and indirect implications) will allow the creative exploitations of technology in envisioned novel applications and approaches ([12]), the development of new aesthetics ([5]) and conventions ([13-15]) beyond traditional forms [5]. Both [12] and [13] are *ISMAR-AMH* papers (2010 and 2011 respectively) of this paper's *first 2 authors* that have specifically fronted the understanding of technological limitations to be a design requirement when envisioning designs for handheld AR (HAR) gaming experiences.

1.1.3 Creative Apprenticeships

The involvement of practitioners and students of creative arts through varying degrees, purposes and goals in technology-oriented initiatives can be seen or described as related work in the following literature – *using evolving AR technology (fiducial*

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IEEE International Symposium on Mixed and Augmented Reality 2012
Arts, Media, and Humanities Proceedings
5 - 8 November 2012, Atlanta, Georgia
978-1-4673-4665-8/12/$31.00 ©2012 IEEE

markers) as an artistic and aesthetic medium of self-expression [5], *building an AR-painting interface to support a specific art style* [16], *teaching design through the development of an AR game* [17], *practical production management skill training* [11], and *structuring higher education (PhDs)* [8], etc. Practical training from real-world projects has been increasingly included in academic curriculum (Section 2.1 in our case and in [8]). In an *artist-student* collaboration (where an arts practitioner works with a technical developer-student), the biggest risk in having student effort apart from professional efficiency and inexperience is not knowing if the project would deliver a working system or not, resulting in an entrenching sense of insecurity [2]. We liken to think the same of the exact opposite collaboration style – a *technologist-student* arrangement where end outcomes as creative design executions of technology(ies) bears the same perceived risk and consequence of being unworkable and thus produce the very same negative disposition of uncertainty. To this end, we would like to highlight that *game design* ([18]) is seen as a specialization in the field of creative arts in this writing, and so the assertions and descriptions that have been detailed so far about artist-technologist collaborations are said to be also applicable to the discipline as well.

1.2 Interplaying Relationships

Research is an inquest into knowledge creation along a journey of learning. Mason believes that the "discipline of noticing" is crucial to the work of researching one's own practice [24]. This paper reflects on the practice-led generative design ([17]) transpirations of a work arrangement with two creative arts students, both as 'full' practitioners in 2-D art and game design developments respectively. The students worked in an interdisciplinary collaborative environment with three researchers from technical (technology), design and social science (education) backgrounds. The aim was to co-develop an outdoor educational location-based game during the students' 6-week ITP (Section 2). Using the resultant design outcomes of the two student-artists, in particular the structured mini-games' ([19]), we inform interaction design by proposing a *single display groupware* ([21]) interface for supporting a dual-player outdoor co-located ([22,23]) HAR gaming experience. We prime our case as a successful development with student-artists that may be useful to inspire future work with such an interdisciplinary design approach.

2 Background of the Case Study

2.1 The Initiative

The Keio-NUS CUTE Center in the National University of Singapore[1] has been hosting student interns from the School of Design's **Games Design and Development** program in **Singapore Polytechnic** (SP)[2] under their 6-week **Industrial Training Programme (ITP)** since 2009. This is also commonly known as an 'internship' in some countries where students are attached to an external organization to gain practical work experience that is relevant to their field of study. For ITP, students receive a fixed stipend to cover basic subsistence costs. A weekly overall progress report is sent to the *Principal Investigator*. In past batches, each student of game design and/or digital art (2-D or 3-D) specialization(s) (varied according to our specific skill set request to the school) was assigned to at least one graduate staff researcher of humanities (social science or design) background, and one other graduate staff researcher of either computer science or engineering background, and worked in interdisciplinary Games-, Education-, Mobile- and/or AR-related projects, i.e. Artwork for the prototype in [12], our ISMAR-AMH (2010) paper was previously co-created by a student-artist under SP's ITP.

Figure 1. Artifacts photographed at National Museum of Singapore, (Left): Portrait of *Sir Stamford Thomas Bingley Raffles*. (Middle, Right): "Jackson Plan" (1822) / Close-up.

2.2 "The Jackson Plan"

2.2.1 Motivation

"The Jackson Plan", also known as the "Plan of the Town of Singapore" is an actual urban town plan drawn up *by Lieutenant Philip Jackson*, an engineer and land surveyor of the British colony, in the **year 1822** to manage the early multi-racial (predominantly the Chinese, Malays, Indians and British) immigrant settlements (Figure 1, Middle & Right), and is named after the same. It is featured as a specific chapter of the history subject for lower secondary students in Singapore public schools that is, *Sir Stamford Thomas Bingley Raffles'* (Figure 1, Left) founding of modern Singapore in the **year 1819** as an important trading seaport ([25]). Several important geographical sites for key historical events and trade activities conducted by the then-populations that followed with the founding are today historical landmarks along *Singapore River* (Figure 12). The learning experience of this history chapter would be made as a *short and light* **location-based game** (LBG) experience with HAR features for selected *contextually-relevant* ([26]) places.

2.2.2 Initial Educational Design Themes

Domain knowledge of the learning content (Table 1, Column 1) was first drawn by the educational researcher from the academic syllabus[3] and translated into design themes (Table 1, Column 2).

2.2.3 LBG Specifications

The game is to be played by a pair of students and each game session would be accompanied by an adult moderator for facilitation ([27]) and safety reasons ([28]). Considering potential straying player-movements during actual game runs with children, we decided to feature a single-display groupware ([21]) play mode using one handheld device (Apple iPad 3rd Generation), thus physically co-locating both players in closer proximity to the moderator. The single-display groupware presentation ([21]) is intended to help retain children's attention, while facilitating discussions and collaborations between the player-pair ([21,23]), noting however that learning effects of the game prototype are not within the scope of this paper.

Well-designed placements of information in virtual or AR systems where communicative intent is specified by a prioritized list of communicative goals make it possible for the experience of a world that does not exist or one that exists at another time or place [29]. Initial gaming concepts are drawn from [30,31], and from the following location-based work for features – the use of a narrative and HAR effects (*geo-registered panorama artwork, photo-taking activity, physical feature recognition through image-*

[1] http://cutecenter.nus.edu.sg/

[2] http://www.sp.edu.sg/

[3] http://www.moe.gov.sg/education/syllabuses/humanities/files/history-lower-secondary-2006.pdf

based AR) to bridge historical contexts to evocative places [32], linearity in narrative design [33], and the use of an adventure game structure [34,35]. To enrich the user experience, 'mini-games' ([19]) are used as game activity segments at selected prominent locations to feature novel interaction(s) (i.e. [36]). Mini-games are short simple games that focus the player's attention on a particular item or event during an exploration process of a bigger virtual game world. The activities may bear well-known game models/genres ([34]) but should be immediately playable so that player can focus on the content rather than on learning how to play ([19]). The end deliverable expected of this co-creativity execution was a functional game prototype.

Figure 2. Direct isomorphic-mapping of game to real-world space.

2.2.4 Defining Real-World Game Space

As the "Jackson Plan" is an actual architectural drawing (Figure 1, Middle/Right) it served as a spatial reference to the game space (the direct isomorphic method [37] was applied in our case), albeit only relatively on the corresponding physical real-world area because of architectural changes over the last two centuries (Figure 2). This mapping process influenced game design (game event placements in Section 3.2.1) as in Figure 3. A quick *bodystorming* ([38]) was conducted at the proposed game site by the researchers to confirm that the selected HAR-technology deployment spots were usable. The associated limitations surrounding the technological features in Section 2.2.3 were determined or at least identified during the session, i.e. image-based AR recognition/ location tracking stabilities were tested at different times of the day. This technique has been found to be useful for *physical site-sensing* [39], and for *LBG ideations* [17]. During the initial conceptualization of the project, there were concerns with the available options for physical AR-feature recognitions (considering sunny outdoor lighting conditions), and with possible GPS inaccuracy issues (as the area is along a river with skyscrapers nearby).

3 METHODS

Sections 2.2.2, 2.2.3 and **2.2.4** were completed ahead as a pre-study by our host group that comprised of three researchers from *technical-technology (rT)*, *design (rD)* and *social science-education (rE)* backgrounds respectively as soon as it was confirmed that two SP students would be working with us in dedicated artist roles (2-D art and game design) as their ITP (Section 2.1), noting however that only one student (the one on 2-D art) was originally assigned to work on "The Jackson Plan". We had intended for this student-artist to take on part of the game design tasks, given that students undergo the same foundation courses in SP. *rD* was the students' supervisor for this ITP, and the project's producer. Both *rD* and *rT* have prior professional experiences in the creative industries. We have excluded the *Principal Investigator* from the host group in **Methods** because we are focusing on the daily interactions and exchanges that the researcher group had with the SP students during the ITP interim.

The remaining parts of this section are – the *knowledge empowerment process* (Section 3.1), *what we did as a group* (Section 3.2), *the co-assignment* (Section 3.3), *individual and sub-group contributions of group members* (Section 3.4), and *iterations* (Section 3.5). Preproduction and production documentations, design notes, logs, and e-mail/oral communication transcripts are used to present this case study.

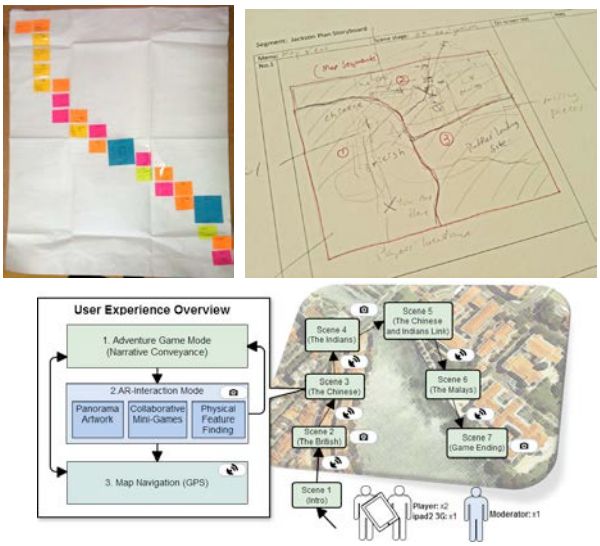

Figure 3. (Top-Left): Game structure for "The Jackson Plan", (Top-Right): Game area / map segmentation discussions, (Bottom): User experience overview.

3.1 Knowledge Empowerment and Access

During the first week we introduced AR technology overviews to both *Student-Artist A (SA)* the 2-D Artist, and *Student-Artist B (SB)* the Game Designer. Both of them had no prior working/industry experience. Although *SB* was initially assigned to another less work-intensive project that was led by another researcher colleague (not in "The Jackson Plan" group), we felt that the lecture might be interesting to him and hence included him in the remaining group ideation activities of this section and Section 3.2.We will however explain later how *SB* was eventually involved with mini-game design work for our project. The following topics were covered using still images, videos and selected research papers during the introduction - 'History of Mobile AR'[4] [40], features that can be used in HAR game design [13][41], common HAR challenges (from our pre-study and [42]), and we provided examples using 'Spirit Camera'[5] and *Games Alfresco's* list of AR games[6]. Technological constraints that we knew of were highlighted along the way. We also allowed the students (where possible) to have 'hands-on' physical plays with HAR software-loaded devices (Apple *iPad 3rd Gen.* and *iPhone4S*) that were accessible during working hours. This turned out to be their first exposure to AR (actual interactions with the technology). Next, we introduced "The Jackson Plan" (Section 2.2.1) using the history textbook ([25]), initial design themes (Section 2.2.2), and images taken during the bodystorming session

[4] https://www.icg.tugraz.at/~daniel/HistoryOfMobileAR/

[5] http://spiritcamera.nintendo.com/

[6] http://gamesalfresco.com/2009/06/27/your-favorite-augmented-reality-games-of-all-time/

(Section 2.2.3). We encouraged the students to talk to the team members on any respective domain subject at anytime.

3.2 Co-Creation Activities (Whole Group)

3.2.1 Narrative and Game Concept Abstractions

A 'Post-Its' session led by *rD* was used to discuss and ideate the **game structure** of the adventure-styled LBG by the group, colored squares represented different game event segments, i.e. scene chapter points including transitions between geo-specific panorama artwork and HAR feature modes (orange), within-scene screen transition points (yellow), dialogues for *Non-Playable Characters/NPCs* (pink), and requirements for mini-games with HAR features (blue), as in (Figure 3, Top-Left). Player-actions and interactions for triggering in-game transitions were discussed and denoted on the individual Post-Its, forming the **narrative's overall flow** in (Table 1, Column 3) that was used in Section 3.4.2.

Table 1. Translations of learning concepts to design elements

Individual Developments (*rE*)		Co-Creations (Whole Group)	
Column 1	**Column 2**	**Column 3**	**Column 4**
Learning Concept	**Design Themes**	**Narrative Development**	**Activity Design**
1. Background of Singapore Settlement	* Small fishing villages * Trading activities at dockyards * Mixed populations (multi-racialism) *British-shops	Players are assigned to locate the missing "Jackson Plan". They are also asked to talk to several people (NPCs) to gather background information.	Players are to pick up virtual items in a geo-referenced panorama artwork of the past.
2. Entrepot Trade	*Daily lives of coolies/workers (multi-racialism) *Middlemen's trade role *Food depot (i.e. rice and tea) *Chinese factories	Players learn the primary trade activities of the population group (importing and exporting of goods) by talking to the Chinese middleman (NPC) in the rice factory.	Players experience the 2-player "*Rice-Packing*" mini-game that requires teamwork using the same device.
3. Contributions of Immigrants	* Emphasis on cotton trade * 'Elgin Bridge'- A monumental bridge that once served as a trading link *Dockyards	Interacts with a virtual Indian coolie (NPC) who explains his job and livelihood to Players. He provides navigational information to the next point of the game.	Players are required to take the photograph of the correct prominent physical feature situated along the predesignated route. They play the "*Rain-Sheltering*" mini-game of synchronized movements.
4. Comparisons of Immigrants' contributions	* A Malay village along the river * Supplies and service provisions (i.e. Malays shipbuilders) * Raffles Landing Site / 'The Statue of Raffles'	A Malay elder (NPC) acts as a facilitator who helps Players to organize and reflect on the overall information fragments from the gaming experiences (who have they met and their respective contributions to the settlement).	Players unlock a secret virtual document through *markerless-* AR recognition of a physical feature at this location (The 'Statue of Raffles' at the Raffles Landing Site).

The game features an in-game map that scaffolds and reveals new destinations as extended map pieces with game progress (Figure 4). This is used in conjunction with GPS navigation to guide players to the predesignated locations that are to be visited, as players would learn during the game. As such, the game area was divided into three segments (Figure 3, Top-Right) in preparation for its art development (Section 3.4.3). A total of **7 scene events** excluding the game's opening title were created from the game structure (Figure 3, Top-Left) and sequentially distributed across the layout of the **game area** from Section 2.2.4 in the order of historic relevance to establish the **user experience overview** as in (Figure 3, Bottom). The resultant outputs of this section allowed the team to have the necessary base references to respectively work on from thereon, either individually or in sub-groups (Section 3.4). We also compiled a report for a content review by an external education researcher with teaching experiences. A master schedule that was negotiated between the group's researchers was drafted at the beginning of **Week 2** based on the outstanding required tasks for the project – a detailed narrative script (mainly developed by *rE* and edited by *rD*, Section 3.4.1), game designs for the mini-games (by *SA*, Section 3.4.2), art assets to be produced (by *SA*, Section 3.4.3), preparations of information architecture, key concept sketches and overall coordination (by *rD*, Section 3.4.4), and system development (by *rT*, Section 3.4.5). *SB* had not been assigned any individual work tasks at this point as he was left to work on the project under the original assignment.

Figure 4. Segmented in-game map (3 pieces).

3.3 The Co-Assignment

Towards the end of **Week 2**, the researcher team co-assigned *SB* (who was at that time working on another project) to the designing of the mini-games in order to keep up with the schedule. Progress had been pressured mainly by the extra time that the team took with *SA* to determine the visual style and detail that could be achieved in the given time for the art assets (the whole process took longer than anticipated).

3.4 Individual/Sub-Group Contributions

We describe the work that was completed by individual team members or sub-groups in this section.

3.4.1 Narrative Refinement (Script)

The final narrative script was prepared by *rE* using (Table 1), and edited by *rD* for context continuity in the game design.

3.4.2 Mini-Games' Developments

As a result of the co-assignment (Section 3.3), *SB* worked on initial conceptualizations for the two mini-games' designs from the discussions of (Section 3.2.1). His specific directions from *rD* were that although not a requirement, mini-games should preferably include HAR features/interactions. *SB* later directly worked with *SA* to assess the design requirements for the mini-games' art assets (2-D graphics).

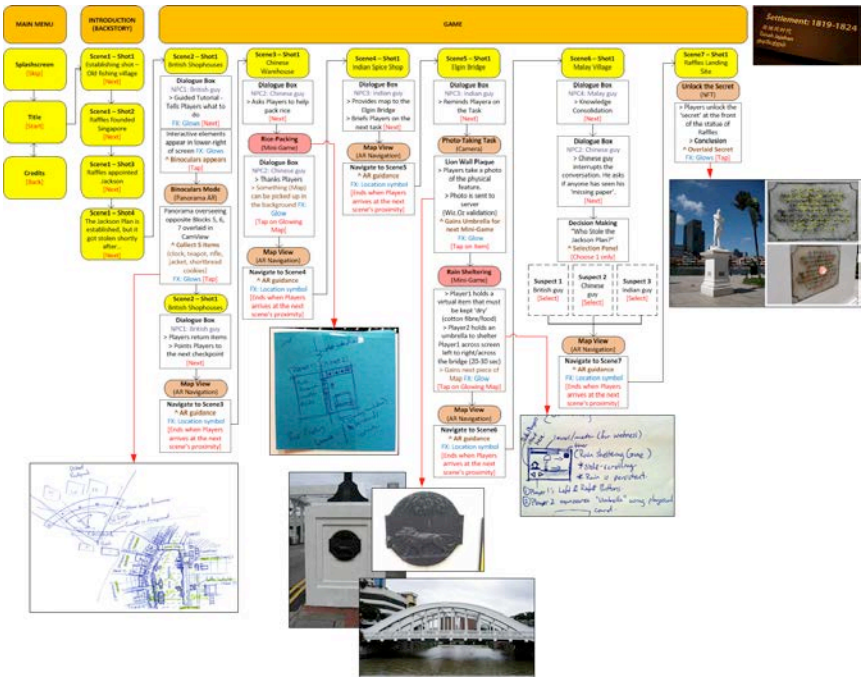

Figure 5. Interaction flow for "The Jackson Plan".

3.4.3 2-D Art Development

The required artwork to be completed by *SA* comprised of the following – artwork for 7 game characters (2 poses each), 12 scene backgrounds, 17 mini-games' UI elements, 5 objects and 1 background for the panorama artwork (using Figure 6 to 'project' the required perspective), 1 in-game map (Figure 4), and 1 splash-screen (main title page for the game). Historical visual references were compiled by *rD* and *rE* from various public sources, including the National Archives of Singapore[7].

3.4.4 Interaction Flow and Coordination

rD prepared an interaction flow diagram (Figure 5) and a conceptual visualization overview (Figure 6) from the group's discussions (Section 3.2) that guided requirements for the mini-games' developments (Section 3.4.2) and the panorama artwork (Section 3.4.3). Figure 5 also charted the information flow in preparation for system development (Section 3.4.5).

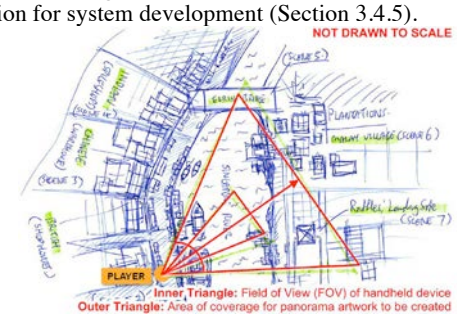

Figure 6. Conceptual visualization overview.

3.4.5 System Development

rT developed the system for the LBG based on the discussed requirements in Section 3.4.4 (Figure 5). The selected platform for "The Jackson Plan" was the *Apple iPad (3rd Generation)* in consideration of the following features – *has a relatively large screen, GPS, gyroscope, camera, and sufficient rendering power for vision-based markerless-*AR *experiences*. *Cocos2d*[8] was used during development to structure the multi-functional system architecture of the adventure game that included character dialogues, game scenes, screen options, and in-game mode switches of the LBG. When it became evident that visual HAR features would be used as designed activities (through Section 3.4.2), Qualcomm's *Vuforia*[9] was included to embed *markerless-*AR support. As *SB* was keen to be involved with system development work, he helped out in *LUA*[10] scripting tasks for the game scenes (sequencing events and character dialogues).

3.5 Iterations

Group meetings although regular (up to twice a week), were usually impromptu due to evolving project needs. During the 6 weeks that passed, there were several instances of interdependencies in the packed activities of Sections 3.2, 3.3 and 3.4 that demanded immediate iterative cycles of feedback and revisions on issues and ideas that surfaced, i.e. we discussed *SA*'s artwork and *SB's* mini-game ideas (Section 3.4.2) to combine narrative and collaborative elements into them (Table 1, Column 4), which were then used to refine the narratives (Section 3.4.1).

4 Results

In this section, we focus to report on the outcomes of *SA* and *SB* for the respective tasks of art development and game-design work.

4.1 First Design Iteration (Concepts)

4.1.1 Art development (Initial Sketches)

Conceptual sketches were initially proposed by *SA* (Figure 7), which required the approval of *rD* (first on the visual element

[7] http://www.nhb.gov.sg/nas/

[8] http://www.cocos2d-iphone.org/

[9] https://developer.qualcomm.com/develop/mobile-technologies/augmented-reality/

[10] http://www.lua.org/

selections and compositions, and later on colors and shading, etc.). *rE* advised on the possible inclusions of appropriate educational themes into the artwork (i.e., Table 1, Column 2). Several of the early conceptual sketches were reworked numerous times in **Week 2**, causing the team's overall progress to fall back slightly. By **Week 3** (which was halfway into the 6-week ITP), *rD* asked *SA* to instead prepare a self-projected task schedule while factoring the remaining work balance and the number of working days left (which was actually only 17 days).

Figure 7. Artwork by *SA* - Line sketches and colored backgrounds.

4.1.2 Ideas for Mini-Games

SB produced 10 mini-game ideas in two days. A few of these ideas had screenshots of existing games to illustrate specific game mechanics or HAR features. The researcher group selected the following two initial ideas to develop further from (Section 3.5),

- **Mini-Game 1**: The Player plays a Siamese worker to put the sacks of rice on the shelves of the storeroom by dragging and dropping the rice sacks.
  - *Scoring is based on time.*
  - *The other player can perhaps control a piece of cloth using an AR marker to wipe off the kerosene before the first player is able to place a rice sack on the shelf.*
- **Mini-Game 2** (Figure 8): Player assumes the role of a worker who has to build a bridge to cross the Singapore River. There are bricks and support pillars that can be used to construct a bridge. The bridge would not hold together if there are no support pillars. The bricks would not hold if no cement is applied.
  - *The first player is only able to move left and right to pick up objects to construct the bridge.*
  - *Players can only complete the mini-game if they get to the other end of the bridge. There is no scoring system.*
  - *Using an AR marker, the second player is able to determine the positioning of the objects. It has to be close to the first character in the game. A button is used to confirm the positioning of the object.*
  - *If Players try to walk across without completing the bridge, they would fall into the river and respawn at the starting point.*

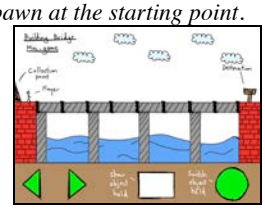

Figure 8. *SB*'s initial concept for Mini-Game 2.

4.2 Second Design Iteration (Low Fidelity Prototype)

Both the mini-games were revised further (described in the next paragraph) by the researcher team to structure player-collaborations through synchronous game activities with embedded contextual information from Table 1. Given the target user audience (secondary school students) and the intended use site (urban outdoors), we wanted an easy and uncomplicated interaction design for these mini-games (i.e. Rules must be simple and intuitive enough such that it would be possible for players to win at the first try). The use of physical AR card markers (i.e. Figure 13) was included to enrich player-interactions and player-scorings were combined from both mini-games.

- **Modified Mini-Game 1 ("Rice-Packing"):** In *SB*'s initial revision (Figure 10, Left) the physical-card holding player's position was on the right side, which we swapped because of the intended orientation of the in-built camera of the handheld device (top left corner from a user's left hand when the device is held up, i.e. as in Figure 11). We also reduced the physical card-orientation options from three to two as we found during playtesting that a complete 180-degree card-rotation gesture was unpleasant and unintuitive to physically perform repeatedly without obstructing the camera's view. Players collaboratively pack sacks of rice in corresponding sequential steps for 'packing' (Player 1, using on-screen UI to perform sequentially-ordered moves) and 'catching' (Player 2, using physical card marker orientations to trigger appropriate 'basket' changing and catch falling colored-sacks in time). Only complete cycles of the two players' actions count towards scoring. 'Mis-packed sacks' (those that have been packed using broken sacks) are to be thrown into the virtual trashcan.
- **Modified Mini-Game 2 ("Rain-Sheltering"):** (Figure 10, Right) shows *SB*'s initial revised concept that depicts synchronous player-movements (numbered 1 to 2 in the green and blue circles) and random obstacles (winds, twigs/stones, and rain as numbered in the black circles 3 to 5) hinder players' movement efforts. The meter-bar (black circle 6) indicates the dampness of the cotton (having been exposed to rain). Player 2 (using a physical AR card marker to control a virtual umbrella) shelters Player 1 (using on-screen buttons to maneuver a virtual cart of cotton stock) to keep the cotton dry while crossing the obstacle-filled bridge.

An offline low fidelity prototype was created in **Week 4** with the inputs of *SA's* artworks (temporary proxies were used for on-going/incomplete parts), and *SB's* reworked mini-game ideas into the system by *rT* that allowed for the independent play-testing of the two mini-games and the panorama art feature by our group members and other colleagues in the lab (Figure 9). Playtesting and preliminary feedback from testers allowed *SB* to propose how the mini-games' interactions should be tweaked and balanced (in discussions with *rD* and *rT*) as the mini-games were initially left in an 'unconstrained' state to explore limitations and extents. Art development by *SA* continued (Figure 11, Bottom).

Figure 9. Low fidelity prototype (left to right): Mini-Game 1, Mini-Game 2, and Panorama Artwork Feature.

4.3 Third Design Iteration (Refined Prototype)

In line with his own schedule, *SA* spent the last few days of the remaining ITP period on artwork refinements. *SB* by this time had completed his tasks for "The Jackson Plan", and was working on another project. For the remaining game balancing tasks, interactions for the two mini-games' were fine-tuned and mapped to constrain parameters by *rT*. In Mini-Game 2 for example, detected physical AR card movements for Player 1's virtual umbrella movements have been constrained to the horizontal axis, i.e. vertical card translations are ignored. Through playtesting of the low fidelity prototype, we found that this constrain eased the control of an on-screen virtual element using a physical gesture. Geo-location service was linked up with game events to complete the prototype (Figure 11). The researcher group only managed to conduct a field trial with the refined prototype after the ITP.

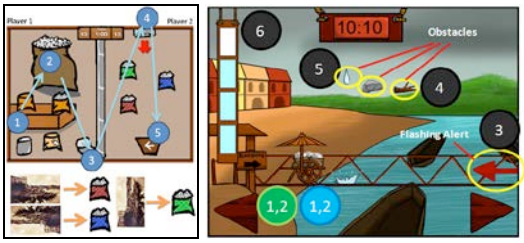

Figure 10. *SB*'s revised concepts:
(Left) Mini-Game 1, (Right) Mini-Game 2.

5 Reflections

The outcomes of practice-led research can be valuable to others who are pursuing the same track [7]. We have presented in detail our experiences (processes, issues, and outcomes) of working with student-artists to develop a LBG game using AR as an evolving technology ([14,44]). While it is easy to differentiate the contributions of artists in conventional practices of arts (i.e., contemporary, fine, or digital, etc.), technologists have long debated whether their own form of creation is purely technical or whether it can be viewed as an art when an *'initial creative spark is fanned into a flame'* [4]. We think that the same debate is valid when creative artists start to pick up technologies to directly work with, as [5] or *SB* (in a way) did.

5.1 Relational Reciprocities

We have shared a real project development that was filled with industry-like requirements, and generatively worked with the two student-artists for most parts as equal stakeholders. Their inputs and opinions became integral parts of the project's designs. On the last day of the ITP, the students were asked for their opinions of their ITP work experiences. *SA* replied, *"It was very tiring"*, and *SB* responded, *"It was fun and interesting"*. We attempt to review these statements and relate possible causes for them.

Despite being able to complete the planned project in the relatively short span of 6 weeks, several compromises were made. Our schedule for the required artwork was reworked on as visual quality (a highly subjective attribute) had to be balanced with realistic time allocations. *SB*'s co-assignment (Section 3.3) was actually due to his confession to *rD* that he did not enjoy game-design, to the extent that he appeared stressed over this initial task allocation (observed by *rD*). The schedule that *SA* prepared later seemingly instilled a sense of self-awareness of his own pacing in relation to how others worked, and he did pick up momentum about a week later. It is apparent that *SB* enjoyed his work very much, as he shared ideas and concepts that blended freshly gained knowledge (technological features and/or limitations). Despite also being in a work environment for the first time, he had a curiosity into (HAR) technology that researchers constantly fed into (knowledge empowerment, [5]).

Figure 11. (Top) "The Jackson Plan",
(Bottom): 180° geo-registered panorama artwork feature.

5.2 Post-ITP In-depth Interviews with Student-Artists

The researchers conducted a 50-minute in-depth interview with each of the two student-artists to follow up with their views on their ITP experiences in order to answer the following questions - *Q1) What issue(s) did the team face during the project? Q2) Did our knowledge empowerment methods enable the co-creativity processes that had led to the final outcomes? Q3) Did the student-artists feel that a collaboration process had occurred between the researchers and them?* In order to elicit appropriate responses from the subjects to help answer these questions, key guiding questions from (Table 2) were used to direct the interviews. We then transcribed their responses from the digital audio recordings.

Table 2. Guiding questions for in-depth interviews

For Q#	Guiding Question (GQ)
1	Which aspects of the ITP did you like or dislike? (i.e. daily routines, task allocation, schedules)
2	Describe how you learned about AR. Which approach do you think had been the most effective/important for you to learn about AR?
2, 3	Describe your main role(s) and tasks in 'The Jackson Plan'
1, 3	What challenges did you face when working with the team members?
1, 2	What difficulty(ies) did the team face during the project? How do you think this was eventually resolved?
2, 3	Do you think that we had omitted something (during the ITP) that might have helped you learn even more (on AR learning)?

Summary of responses for Student-Artist A

Q1. *SA* listed 'communications' as a problem for him and the team. He found it difficult to understand team members (excluding *SB*) at times (*"communications bothered me the most"*) and often had to probe further on communicated topics. As an example, he described how members would query him on missing, mismatched or individually subjective visual details in initial versions of his artwork that were generated from our group discussions. He saw that the extra time for his rework had impacted the team's progress (*"this caused delays to the team"*).

Q2. and Q3. *SA* identified (hands-on) 'demonstrations' to be the best approach for him to learn about AR (*"I think that it is a better approach than only watching videos"*). He described his

exchanges with *SB* to develop artwork for the mini-games and the sharing of his ideas during discussions to be his contributions towards the project, and acknowledged his inputs of ideas during group meetings as being part of the collaboration process that had occurred (*"… I provided views on game contexts that were eventually effected as changes (by the team) in the project."*).

Summary of responses for Student-Artist B
Q1. *SB* did not sense that the team had been experiencing any real troubling issues but mentioned that there were occasional difficulties for him to fully understand the other members (referring to slight differences in language across disciplines). He also felt that (project) changes were effected rapidly.

Q2. and Q3. *SB* successfully recalled and identified all the sources of 'knowledge empowerment' that were supplied to both student-artists – academic papers, web video examples and actual practical playtesting of games and AR interaction concepts during project development. He however also included the 'group meetings' as a source of learning for himself. *SB* attributed that these sources were equally important for him to learn about AR.
SB claimed ownership of the mini-games' designs and game scripting tasks, and included his inputs during the group meetings as one of his contributions to the project through the following transcribed statement - *"I sometimes gave comments during our meetings. In particular these were the occasions when we discussed which (game concepts/types) were better suited for specific locations (referring to the distribution of the game activities across the physical game site). For instance, (I suggested) that some game types might be better suited for certain locations."* He eventually described processes that happened through the collective efforts of the group and exchanges – i.e., *"The splitting of the map into 'treasure-map-like' pieces was also something that* ***we did together****."*

Interpreting responses for Q1
We want to see if the student-artists had noticed either the co-assignment (Section 3.3) or rescheduling (Section 4.1.1) incidents. To answer this question, they must explicitly identify *SA*'s work progress during the project as the main cause for these events.
Result - Citing personal experiences, both student-artists reported that they had faced communication issues with team members during the case of 'The Jackson Plan'. It turned out *SA* himself identified that this problem had impacted the team's schedule.

Interpreting responses for Q2
We want to highlight that 'knowledge transfer' (from the researchers) had enabled the student-artists to work with AR media. To answer this question, the student-artists must associate or recognize that their self-identified areas of work as contributions to the group-based AR design activities, and final outcomes.
Result - The student-artists recognized and related their own respective inputs (work and ideas) as part of the project's AR design and execution processes.

Interpreting responses for Q3
To answer this question, the student-artists must describe some sense of mutual exchanges of work and ideas between themselves and the other team members that had contributed to the project's design processes and/or final outcomes.
Result – Both the student-artists cited their contributions of ideas in several of the group-based activities (discussions, meetings, actual design processes and playtesting sessions).

Figure 12. The Singapore River: Play site for "The Jackson Plan".

5.3 Informing Design and HCI

Situated contexts that are exemplified through storification and the consideration of technological limitations seem to be able to justify design decisions of location-based HAR game attributes. In our case, the authors sought to create a learning experience of representing 'living in the past' in the historical context of "The Jackson Plan" (Figure 13) that would allow a pair of players to collaboratively 'interact' with contextual information at given points of location-induced opportunities during gameplay. This inspired a HAR user interface where visual and tangible game controls have been embedded to support collaborative communication designs. We will next look at how aspects of the design outcomes from the recent experiences gained through the development of "The Jackson Plan" may be used to inform interaction design in HCI ([45]).

Figure 13. Reflecting the Past in Present[11].

5.3.1 Digital Evolutions

Amidst an evolving landscape of digital cultures and the public's notion of digital interaction, [20] introduced a categorization of classes of digital interaction to use video game culture as a metaphor to redefine local digital culture by the degree of physical interaction, *'liminal'* as the less physical-digital (i.e. using a conventional gamepad's button push to represent the metaphor for kicking a ball), and *'transitive'* as the more physical-digital (i.e. physical computing systems such as Nintendo's Wii[12] where user's actions are always an integral part of the interaction itself). In their work, user-to-media relationships are drawn by intersecting *luminal/transitive* interactions to *control-* (the computer science approach of user to medium focus) and *communication*-based (human communication theory of user to user focus) interactions, producing the definitions of ***operational*** (combination of *control-communication* and *liminal-transitive* interactions) and ***relational*** (combination of *communication* interaction with both medium and dialogic interactions) **senses of interactions**. These definitions are used to describe a piece of interactive media (art installations, video games, and new media) according to the degree of **user's control**, **sense of involvement** and **primary function** (i.e. *control-based transitive interaction*, or *communication-based liminal interaction*, etc), noting that the most crucial aspect of this classification is that digital culture cannot be considered without concerning socially-motivated local digital culture (which is multi-variate and difficult to define).

[11] Original postcard from the *Lim Kheng Chye's* Collection (archstudio@pacific.net.sg)
[12] http://www.nintendo.com/wii/

5.3.2 Interpretations

In consideration of the **core design** (relational) and **purpose** (operational) of the proposed player-interactions in the two mini-games' designs, we describe using [20]'s multi-cultural definitions of interaction that these are situated on the very point of intersection between *liminal-transitive* and *control-communication*-based interactions. Being on the crossroad juncture, apart from bearing all the four traits of interactions, requires an instilled **equinoctial sensitivity** in the *media creator* for its development; the metaphor of an 'equality of light and darkness' has been used to associate the encapsulated understanding of technologies through the knowledge of their strengths and limitations. We position that both student-artists had acquired this 'sense' through their own acknowledgements (during the in-depth interviews) that they fused AR and art (game design) knowledge into this project's development.

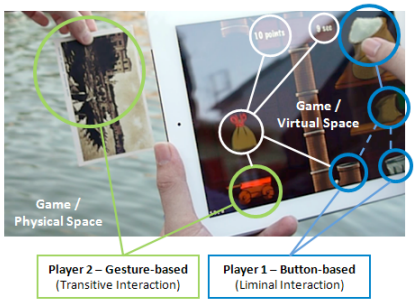

Figure 14. Interpreting Mini-Game 1.

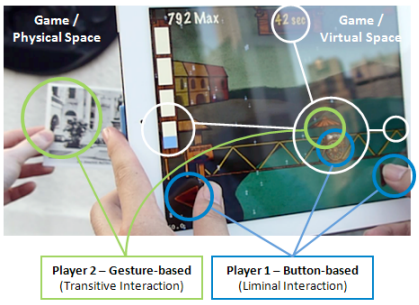

Figure 15. Interpreting Mini-Game 2.

Both the user interfaces for the HAR mini-games (described in Section 4.2) offer combined ***liminal* and *transitive* interaction** features in a single cross-media game space ([12]) that are bound by *action and reaction mechanisms* (*control-based interactions*) and *co-located*-players' *awareness of one another* ([21,23]) (*communication-based interaction*) to collaborate and overcome common game goals, i.e. Player 1's moves are *liminal* (button-based) while Player 2's moves are *transitive* (physical-based) but they are dependent on each other's actions and intercommunications to win the mini-games and advance in the LBG as a common goal, as in (Figure 14) and (Figure 15). Featured game interaction tie-ins in the user interface (i.e. the physical AR card marker) may be replaced or redesigned with other technological features or game mechanisms such as other digital sensing and identification technologies (including location-inference techniques, and in the near future, gesture recognition and projection features as well). The design of this user interface has also factored significant real-life operational conditions from its intended use-contexts (Section 2.2.3), such as the pragmatic need to co-locate children-players in closer proximity when an educational LBG is run by a single moderator in traffic-laden urban environments, and (trying to) retain children's attention on the specific task(s). **Equinoctial sensitivity** is thus also about crafting practicality in experiences.

5.4 Contribution

Practice-led research in arts and sciences (technology) is always propagated by a highly responsive and iterative exchange where new insights are quickly fed back into the development process to foster the co-evolutionary processes that happen in tandem within the collaboration [3] for all the parties involved. Technology use then yields new answers that may lead to the transformation of existing forms and traditional practices across disciplines. Ensuring that materials from every participant are usable is a major challenge in a co-creativity process. Working with student-artist collaborations can be successful when critical issues are properly identified and addressed despite rapidly evolving and changing project requirements [2], which this paper can be said to be a witness to.

The combined (selective) artistic outcomes of the two student-artists who worked in the interdisciplinary environment have also informed an interaction design for a collaborative co-located single shared interface for an outdoor location-based HAR game. Apart from gaming and edutainment, we foresee that it can be useful for creatively supporting user experiences in outdoor training, advertising and tourism applications.

6 Conclusion

We see the roles of the student-artists in "The Jackson Plan" as a successful co-creativity execution of artistic intimacies with intertwined interdisciplinary AR knowledge. Future work for this research will be to explore communication issues in the co-creativity processes of interdisciplinary AR media design.

As the ISMAR-S&T and ISMAR-AMH communities both seek for new blooms of inspirations and perspectives to innovate AR user experiences from, it is perhaps also a good time and opportunity for us to provocatively reflect on how we may as harbingers ignite co-creativity processes together.

Acknowledgements

This research is partially funded by project no. WBS R-705-000-025-271, a grant from the National Research Foundation through the Ministry of Education of Singapore, and project no. WBS R-705-000-029-592, an industry research grant from ST Electronics (Info-Software Systems).

We would like to thank the School of Design, Singapore Polytechnic for their support and interest in our research projects over the years, and to DGDD students *Lim Hong Kwan* and *Chen Yuyang* for working on "The Jackson Plan".

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