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Author post-print (accepted) deposited in CURVE February 2016

Original citation & hyperlink:

Lameras, P. , Pisithpunth, C. and Petridis, P. (2015) THE GROWTH: A quiz-based game for addressing growing population issues: Linking learning mechanics to THE GROWTH serious game.. 2014 International Conference on Interactive Mobile Communication Technologies and Learning (IMCL): 344-349

<http://dx.doi.org/10.1109/IMCTL.2014.7011161>

DOI 10.1109/IMCTL.2014.7011161

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THE GROWTH: A quiz-based game for addressing growing population issues

Linking learning mechanics to THE GROWTH serious game

Abstract—This paper discusses the learning effect from an environmental game in a randomized controlled trial (RCT). The knowledge outcomes from 82 participants are compared and discussed in both quantitative (factual knowledge scores) and qualitative forms (interview statements & behavioral intention).

Environmental problem is currently one of the most important global issues. The world is facing ecological problems such as global warming, declining biodiversity, unsustainable resources consumption, and pollution contamination. Studies have agreed that human activities are the main cause for environmental problems [1], [2]. Further, the current trend in rapid population growth will amplify the pressure on natural environment [3]. For example, the main cause for deforestation has stemmed from the necessary to expand farmlands to satisfy food demands of growing population [4]. At the same time, the demands for energy and commodities from industrial manufacturing are projected to increase. Water shortage is recognized in many regions worldwide [6], [7], implicating sanitary and health issues. Further, water shortage amplifies risks of famine due to agriculture sector's dependent on water [8]. Waste problem is another major environmental concern where improper waste disposal can pose serious environmental and health risks [9]. In short, environmental problems will be reflected back to the society – implicating health and wellbeing issues, increase vulnerability to disasters and resources shortage, and even the possibility of conflicts and wars.

Apart from policies and laws, environmental awareness is a crucial element for conservation effort. Reference [10], for example, has highlighted major environmental and economic gains from environmental education. While traditional classroom-based learning, documentaries, and fieldworks can be used to support environmental awareness, some studies are exploring opportunities to integrate environmental education into game platforms owing to game's comparatively lower operational cost and engaging characteristics [11], [12]. Thanks to computer technology, today's digital games can simulate complex level of interactions and provide instant feedbacks to players.

Already a number of Serious Environmental Games (henceforth refers to as SEGs) have already been designed to tackle different aspects of environmental issues. Some SEGs are focused exclusively on a single environmental issue while others have attempted to address multiple issues. In

this paper the authors discuss about the implementation of THE GROWTH, a quiz-based SEG with a special focus on the growing population issue.

I. RECENT SERIOUS ENVIRONMENTAL GAMES

Serious Environmental Games come in various genres and styles. Examples of turn-based ESGs include: FATE OF THE WORLD and BBC CLIMATE CHALLENGE, both games were designed to tackle global warming issue. Real-Time ESGs include ENERCITIES and PLAN IT GREEN, both games were focused on sustainable habitat planning. Some games come in traditional paperboard style. Paperboard ESGs include ENVIROPOLY and DEEP SEA DESPERATION, both games were focused on pollution and wildlife conservation. Interestingly, some developers also consider adventure genre for the creation of ESGs. JOM KITAR SEMULAR for example, is an adventure game focused on recycling issue. There are also 'mini-ESGs' –short and linear games relying on few simple game mechanisms to address certain environmental issues.

It is also important to consider commercial games with environmental characteristics as well. ANNO 2070 for example, is a city-management game that envisages the future where the global warming has altered earth's continents into chains of islands. The game highlights interrelationship between habitat expansion, economy, technology, security, natural resources, and environmental contamination. For example, growing city generates larger amount of income, but at the cost of increasing resources consumption and environmental degradation. Social problems and disasters (both man-made and natural) occur throughout the game. For example, high level of air pollution in the city will cause illness for citizens. In turn, new technology can be used to mitigate environmental and social problems. I AM ALIVE is a survival game with a background story of the region suffered from a major earthquake disaster. Common commodities such as canned foods and water bottles are vital for players' survivability. Air pollution (i.e. smog from rubbles) presents health hazard for players, forcing them to seek higher grounds constantly in order to avoid long-term damage to health. The game also highlights themes of social chaos such as armed robbery, sexual assaults, slavery, and cannibalism. FATE OF THE DRAGON (FOD) is a real-time strategy game that highlighted the interrelationship between natural

resources, food supplies, and population. The game is set in an ancient China where players assume the role of warlords commanding army camps. Players have to provide resources for their army constantly. Failure to do so will weaken troops' combat performances severely. Resources in FOD are finite. Woods, for example, is the basic resources in this game (for construction and producing foods). Deforestation can occur in long game sessions where trees are cut down to sustain large army (and other war efforts).

II. LEARNING FEATURES

Studies have shown that Game-Based Learning (GBLs) can be used to enhance learning outcomes [13], [14]. Further, players find games to be enjoyable and motivating [15]. Studies have suggested that computer games can be used to promote awareness, enhance learning capability and improve motor skills and alteration of behaviors [16], [17].

Learning model in games can be categorized into: (1) passive learning, (2) active learning and (3) experiential learning respectively. Passive learning can be compared to traditional learning setting (i.e. classroom) where learners passively absorb textual and audiovisual information from the learning medium (or an instructor). Digital games also provide specific sets of information and feedback to players automatically when needed (e.g. hints and clues) [11]. Players may intrinsically seek to acquire the information based on personal interests. They may also want to learn from manuals in order to gain mastery over the game [12] or there might be extrinsic pressures such as the need to improve academic performances or career-related skills. While passive learning is an important step in learning progress, this step alone cannot guarantee efficient learning outcomes due to the lack of active participatory and self-reflection.

Active learning, on the other hand, encourages learners to recall and exercise their knowledge (e.g. quiz and puzzle). Quiz can be seen as a classic example where players are required to choose the correct option (or answer) in order to gain scores or progress to the next stage of the game. Quiz has been long used in various settings such as traditional classroom activities, edutainment products, and in TV shows. In respect to the learning context, studies have suggested that quiz can be used to enhance learning outcomes. For example, quiz can be linked to 'Inquiry arousal' [18] which could be used to promote learners' curiosity and attention. Reference [19] has concurred with this and further highlighted that quiz encourages learners to exercise their knowledge and can be used as an effective learning mechanism in digital serious games. The key advantage of utilizing quiz mechanism in digital serious games is instantaneous performance feedbacks that are provided by the game to players – facilitating learners' level of confidence [20]. Instantaneous feedback also helps sustain

concentration [21] and reinforce players' intrinsic motivation [22].

Finally, experiential learning in games is concerned with 'learning by doing'. In this context, an environmental game may let players manage multiple resources types, balancing environmental condition with economic growth, and making plans for the future while hundreds of other game variables are interacting with one another dynamically 'behind the scene' (e.g. opposing groups, political intervention, and other economic drives). This learning aspect can be linked to what [23] described as 'Learning by Osmosis' – the situation where a person is engaged and perform a complex activity without an explicit set of instruction.

III. THE GROWTH

THE GROWTH is an environmental city-management game targeting adolescents and adults. The game is focused on growing population issue and its implications on natural environment and social wellbeing. Household effluences are emphasized in this game to emphasize 'non-point sources' environmental issues. The game demonstrates relationship between growing population, resources constrains and environmental issues (e.g. growing population consumes resources at increased rates and accelerates the process of environmental degradation). Unlike games with 'environmental-only' model, THE GROWTH emphasizes on long-term economic and societal wellbeing models to demonstrate the importance of healthy ecosystems. For example: turning-off electronic appliances and invest in sustainable technologies to reduce utility cost, conserving wildlife and natural habitats for long-term scientific benefits (e.g. forest products and tourism), and efficient use of resources to reduce pollution emission and health hazards.

THE GROWTH has a background story of the region after a severe industrial disaster, causing serious environmental contamination in the region. The game envisages a situation where humans can no longer afford to expand further into natural environment in order to avoid the ecological collapse. In this game, players take a role as the leader of The Environmental Consortium (TEC) – the government's front organization tasked with protecting the natural environment in the region. Players gather resources which can be used to fund the development of environmental and social projects (e.g. forest protection, sustainable technology, and family planning program). Players can invest resources into businesses which generate steady flows of resources and other beneficial effects back to players over time (e.g. organic farms, public transport company, renewable energy company, and high-rise apartment complexes). Players can further customize these businesses to suit their needs. For example, players can upgrade their wind farm complex with the new sustainable energy storage system and new wind turbine design.

These improve energy production and overall efficiency of the wind farm complex, generating environmental and financial bonuses for players. However, some improvements require players to contemplate between environmental and financial gains. For example, players can order their transport company to lower ticket prices in order to encourage the use of public transportation. This gives environmental bonus to players (from decrease usage of private transport), but at the cost of income reduction. Similarly, farms can be ordered to house animals in high-density, but at the cost of environmental degradation (from antibiotic usage) and runs the risk of disease outbreak. There are four game factors in THE GROWTH. These being: (1) Population factor (2) Environmental factor (3) Emergency supply factor, and (4) Financial factor. Population grows exponentially in this game. Large population size deteriorates environmental condition and consumes emergency supplies rapidly. There is no clear win condition in the game. However, players lost the game once environmental condition falls below 20% (to represent situation where environmental condition has degraded beyond recovery threshold). Similarly, players lost the game when supply factor reaches 0%.

Natural disasters, man-made disasters, and social problems can occur throughout the game. This game mechanism attempt to raise players' awareness on environmental and social uncertainties (e.g. floods, fire, invasive species, crop failures, armed conflicts, war refugees, and disease outbreaks). Some actions can be taken to reduce or mitigate these problems. At the same time, the public may contribute their supports toward players' causes if players have invested considerable efforts to protect their environment.

IV. IMPLEMENTATION OF QUIZ FUNCTION INTO THE GROWTH

As with the three learning categories mentioned above, Quiz (active learning aspect) is the central activity in THE GROWTH as this function is the primary source of in-game resources for players. Quiz represents player's campaigns to raise environmental and social awareness to their citizens. There are over 160 quizzes in THE GROWTH covering environmental, social, and technological issues. About 60% of quizzes in the game are focused on regional issues in order to attract target players to environmental and social issues in their surrounding (Thailand for this case). Another 40% of quizzes are issues from global perspectives. There are two types of quizzes in THE GROWTH. The first type requires players to choose the correct answer from the list of four answers. The second type requires players to read an article and determine whether the article represents environmental issue, social issue, or technological advancement. Quizzes are presented to players in a random sequence.

Depending on the quiz type, a correct answer helps reduce environmental problems, reduce population size and increase players' incomes. For example, the game rewards the player with population reduction bonus for a correct answer on social problem question. On the other hand, players will be penalized for wrong answers where substantial amount of resources will be withdrawn from players' resources pool. Some questions contain 'partially corrected answer' where players will be rewarded with minor amount of resources (some questions can be considered both environmental and social issues). Knowledge of Result (KR) [24] was used to give immediate feedbacks to players once an answer has been selected. This approach was selected to facilitate the flow of gameplay and to limit players from other information distraction.

V. PARTICIPANTS

82 Bangkok-based, Thai-nationality voluntarily participated in the experimentation. The mean age for participants is 26. The reason for selecting adolescent and adult participants for the experiment was due to supposition that (1) the group would be able to grasp basic concepts of environmental and social issues presented in this game (2) the context of economic incentive, social wellbeing, and health benefits from natural conservation emphasized by the game will have more value to adolescents and adults than children (3) Adolescents and adults are key actors in the society (e.g. they have purchasing power and are responsible to make life decisions). After the random assignment, 42 were allocated into the experimental group (playing THE GROWTH) and another 42 allocated into the control group (using a non-interactive reading material based on THE GROWTH).

VI. PROCESS & RESULTS

Due to time constrains, purposive sampling method was used in this study (i.e. non-probability sampling). Efforts have been made to prevent transfer of knowledge between participants prior to the session (i.e. contamination). Each session was conducted individually. Based on their assigned study groups, all participants were given five minutes briefs about the game / the reading material prior to the sessions. Factual knowledge gains were compared between results from pre- and post-test. Semi-structured interviews were used to probe participants' game reception, reflection, and behavioral intentions. The interviewer had adopted a neutral stance and participants were encouraged to express their viewpoints freely and in depths during sessions (full interview statements not presented in this paper).

Further, gameplay data were recorded during sessions and later analyzed to observe players' performance and interaction (for the experimental group). Although not informed until the end, each

participant was given a small gift after the game session (equivalent to the value of £2.00).

The pre-test scores between the two study groups were not statistically significant as determined by the independent-sample t-test (Experimental group: $M = 8.20$; $SD = 1.96$ VS Control Group: $M = 8.83$; $SD = 3.21$); $t(80) = 1.08$, $p = 0.28$. However, the score patterns changed in the post-test with the experimental group gained higher scores (Experimental group: $M = 16.63$; $SD = 3.55$ VS Control Group: $M = 13.32$, $SD = 3.76$). The result appeared to be statistically significant as determined by the Two-way repeated ANOVA ($F(1,78) = 43.86$, $p = 0.006$) – indicating that THE GROWTH has a greater learning effect when compared to the reading material.

As the maximum amount of time that participants may spend in a given session was not defined, the amount of time that participants' spent on the learning medium (time-on-task) could indicate their level of engagement. The experimental group appears to spent longer time on the game compared to the control group on the reading material (Experimental Group: $M = 28.292$ $SD = 11.09$ VS Control Group: $M = 16.487$ $SD = 4.301$). Although this indicates the experimental group participants' greater engagement level with the game activity compared to the control group on the reading material, the longer time on task did not predict the greater learning outcome statistically for both groups (Experimental Group: $r = 0.2753$ / $p > 0.05$ VS Control Group: $r = 0.1015$ / $p > 0.05$).

In agreement with the finding above, the experimental group rated their experience with the game more positively when compared to the control group rated their reading material as determined by the QUIS (Questionnaire for User Interaction Satisfaction survey) [26] – indicating that game-based approach can be an attractive learning medium, at least in the environmental education context.

The interview involves having participants recall and describe the topics from their respective learning medium. The experimental group appears to recall more topics compared to the control group and the result appears to be statistically significant (Experimental Group: $M = 9.24$ $SD = 2.37$ VS Control Group: $M = 7.34$ $SD = 1.79$); $t(59) = 3.35$, $p = .001$. The growing population issue was recalled and discussed by a number of participants. The majority of participants from both study groups who recalled on the growing population topic have suggested 1-2 as the maximum number of children per family. The reasons provided appeared to stem from societal drives rather than ecological ones (e.g. welfare issues, narcotics, and crimes). For other environmental topics, the economic and financial incentives appeared to be the motivating factors for many participants during the interview (e.g. 1) protect the natural ecosystem to improve agricultural outputs and tourism and 2) eliminating polluters to minimize governmental spending). Additionally, the majority of participants have

expressed supportive attitudes towards sustainable technology, mainly for the long-term financial and / or convenience provided by the technology rather than ecological reasons. Interestingly, older participants and / or those with working backgrounds also appeared to reflect on technological topics (as well as other topics) more critically when compared to many younger participants or participants without working backgrounds. For example, some older age groups described and expressed their interests in solar energy systems, but also critical about factors such as the capital cost, return of investment (ROI), maintenance / replacements, reliability, and portability. Similarly, some business models were criticized (e.g. compatibility and replacement issues in electronic appliances and equipment designed to malfunction after a specific amount of time).

Pro-environmental actions such as forest protection, water / energy conservation, public transportation, and recycling were discussed by participants. A follow-up question was administered on each topic to understand participants' behavioral intention. It appeared that the majority of participants have declined to support these environmental – both financially and / or physically. For example, the majority of participants from both study groups have declined to support the 'environmental tax proposal (price increase for all unsustainable products), declined to use public transportation on the daily basis, and declined to practice recycling. According to a number of participants, their reasons rested in many interesting socio-political issues. For example, some participants have declined to support government's environmental programs because of the perceived corruption and inefficiency. Some participants have declined to use public transportation and citing safety concerns, poor timetable, and the slow speed as their reasons. Additionally, some participants have declined to practice recycling due to the lack of financial incentive and / or accessibility issues. These highlighted the real-world obstacles that could discourage pro-environmental actions.

VII. DISCUSSION

This paper has discussed the implementation of quiz-based environmental and social game with a special focus on growing population issue. Similar to findings of positive learning outcomes from other serious game researchers mentioned above, the results have shown that games can be used to promote environmental and social awareness in participants. However, we have observed the gaps between knowledge gains and real-world actions where a number of participants have gained knowledge, but also reluctant to partake in environmental-friendly actions due to the perceived real-world constrains. This highlights that THE GROWTH alone might not be sufficient to encourage pro-environmental attitudes. The combination of real-world incentives and policies

might be useful to tackle these issues [25]. As with experiments run with purposive sampling method, it is not possible to generalize the results to other contexts.

VIII. CONCLUSION

This report suggests that the current implementation of quiz-based digital games can be used to promote environmental and social awareness to players. Participants appeared to perceive the game as more attractive / engaging when compared to the non-interactive reading material – highlighting the possibility of using games to supplement classroom-based environmental learning. Gaps between knowledge and pro-environmental attitudes prevailed and must be tackled by other methods.

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