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Gamification of Environmental Impacts in Digitial Media Abstract
Social norms affect people's attitudes, intentions, and behaviors. Thus, creating green awareness, in particular conveying the concept of environmental impacts to young generations through educational programs, is crucial to the success of the ultimate sustainable development. As sustainability is an abstract concept describing human interactions with complex ecological and climate systems, it is important to let our next generations appraise the consequences of environmental impacts and to nurture them to behave in a way with minimal environmental impacts. This paper presents some of the 'green' initiatives that are implemented in Hong Kong. The aim of these initiatives is to provide simple models of complex systems, deployed in digital media making use of cloud technologies, online interactive games, and competition to raise green awareness among high school students. The results indicate that, with enough support and freedom, students can come up with their own green ideas rather than passively rely on what they have learned from textbooks.

1. Introduction

Sustainability and environmental protection have been major concerns worldwide since the publication of "Our Common Future" by the World Commission on Environment and Development (WCED, 1987). The Report (WCED, 1987) and many subsequent writers (Cairns, 2004; Durning, 1992; Meadows, Meadows, and Randers, 1992) argued that humans should not follow past practices of mining, drilling, producing, polluting, consuming, trashing, and burning in an ever-increasing rate because we live on a finite planet. Most of the material and energy resources we use today have taken millions of years to accumulate and transform. They are in general stored deep underground or in ocean beds. When a society develops, people build buildings, parks, roads, railways, ports, airports, and utilities including water supply networks, drainage networks, wastewater collection networks, power networks, gas networks, and telecommunications networks. People transform lands to urban and sub-urban environments and affect the natural geographical and ecological settings in an irreversible manner. Day in and day out people exhaust more resources to support the modern life and people living in cities are isolated from Mother Nature.

Over the past decades, the United Nations have passed and enacted international environmental agreements such as the Convention on Biological Diversity, the Kyoto Protocol and the Montreal Protocol (UNFCCC, 2013). Numerous governments have passed and enacted local environmental laws and regulations such as the Clean Air Act of 1970/1977/1990, the Clean Water Act of 1972 and the Superfund of 1980 in the United States, environmental-related directives in the United Kingdom, environmental protection laws in China and the Noise Control Ordinance and the Air and Water Pollution Control Ordinances in Hong Kong (Jones, 2005). Many governments spend millions of dollars a year in raising peoples' awareness on environmental protection through advertisements and campaigns on television and radio and in newspapers, and magazines (Li and Li, 2012). On top of these activities, a large number of non-profit organizations such as the World Wide Fund for Nature and Green Peace, among others, have launched environmental campaigns via public and social media. Nevertheless, sustainability is an abstract concept describing human interactions with complex ecological and climate systems while environmental protection involves a good understanding about the likely environmental impacts due to the use of buildings, all kinds of man-made systems, processes, products, and facilities. Hence, raising awareness of environmental (or green) issues can enable the sustainable development of a country/city in long-run (Li, 2009, 2011; Li, Liu, and Li, 2012). In fact, the best approach to raise green awareness is to nurture the youth through education, guiding, and coaching.

This paper describes some initiatives and the implications of using gamification of environmental impacts in digital media.

2. Environmental Education and Information & Communications Technology

In Hong Kong, environmental studies are part of the curriculum in primary, secondary, and tertiary education. A wide range of topics such as non-renewable and renewable resources, energy, pollution problems, global climate change, and biological diversity are covered in subjects including integral science, physics, biology, and geography at the primary school and secondary school levels (XNT et al., 2012). In tertiary institutions, universities and colleges offer courses such as environmental science, environmental engineering, or even more specialized ones including energy management, atmospheric air pollution, noise pollution, wastewater treatment, waste management, forestry, and biodiversity. Nevertheless, students primarily rely on textbook materials supplemented with photos and videos at the primary-school and secondary-school levels (XNT et al., 2012). As Hong Kong with a land area of 1,000 km^2 and a population of 7.1 million is one of the most populated areas and cities in China, most Hong Kong teenagers who were born in the 1990s have been deprived of opportunities to see, touch, and feel Mother Nature. Teenagers spend most of their time studying in schools, attending classes in tutorial schools or centers, and taking extra-curricular activities in other indoor environments. On weekends, they spend their precious free time with

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friends or family members in shopping centers and cinemas. Seeing and touching the natural environment is a rare experience for them (Lee, An, Chan, and Kwan, 2000). Teenagers in other Chinese cities such as Macao, Guangzhou, Shanghai, and Beijing would have the same situation.

With the advancement of Information and Communications Technology (ICT), teachers have more resources and channels to impart students with new scientific knowledge (Donnelly, McGarr, and O'Reilly, 2011; To, Lai, and Chung, 2013). On the other hand, students learn better because of high interactivity and immersion of ICT under proper deployment (Ng, 2010; Yang, Wang, and Kao, 2012). In fact, ICT can enable teachers and students to focus on important aspects of content (Oldknow, Taylor, and Tetlow, 2010), to investigate and analyze problems in more depth (Tasouris, 2009), and from multidimensional perspectives. In addition, as suggested by Herbert A. Simon - a Nobel Prize Laureate in Economics and his fellow associates, humans learn from examples and learn by doing (Anderson, Reder, and Simon, 2000). ICT provide a rich learning environment so that students can see more examples, and make strong connections between what they are learning and their lives. It also allows students to practice (i.e. do) more than just listen. As environmental issues are multi-faceted and interrelated, it is difficult for high school students to understand the interconnectedness of environmental, technological, and economical aspects of environmental impacts and their solutions without visualizing the consequences of various environmental problems and how solutions work. In order to engage and enable students to explore ways to minimize environmental impacts, an ICT-related green platform has been conceived, developed, and deployed to hundreds of Hong Kong high schools, based on the core technologies, Green Tech 3D, of the GreenXity platform. In realizing that many students and teachers may log in to the platform simultaneously, a cloud-based infrastructure was developed that supports a multi-input multi-output environment. The infrastructure also facilitates load-balancing and simultaneous queries from different users. Figure 1 presents the conceptual system deployment and the screen shot.

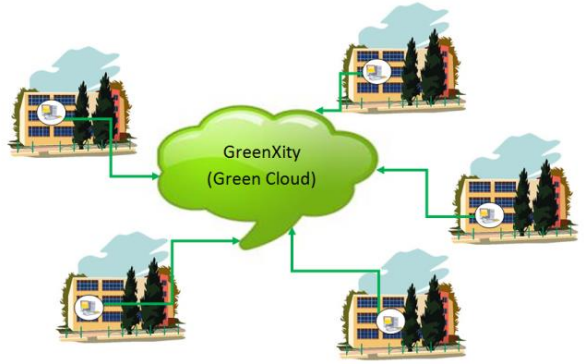

Figure 1. GreenXity Hong Kong

3. Gamification of Environmental Impacts Using ICT

While the deployment of ICT causes environmental problems due to the consumption of material resources and electricity, the use of ICT can help in solving environmental problems (Murugesan, 2008; Tomlinson, 2010). In the past few years, there has been a paradigm shift from greening of IT i.e. Green IT 1.0 to greening by IT i.e. Green IT 2.0 (Murugesan, 2008). Nowadays, green IT/ICT does not only refer to the design, manufacture, use, and disposal of ICT products and systems environmental friendly, it also encompasses the use and integration of ICT products to create resource-efficient, environmentally sound business practices, processes, and solutions, as well as to support environmental initiatives and create green awareness (To, Lai, and Chung, 2013). Young generations were born and have grown up in a time period that is full of ICT-related environment. Research evidence shows that the gamification of difficult concepts arouse student interest and engage their involvement in seeking information (Dillahunt, Becker, Mankoff, and Kraut, 2008), and even can improve their health (Lin, Mamykina, Lindtner, Delajoux, and Strub, 2006).

Like what Anderson, Reder, and Simon (2000) indicated, "Learning requires a change in the learner, which can only be brought about by what the leaner does. The activity of a teacher is relevant to the extent that it causes students to engage in activities they would not otherwise engage in. The task is to design a series of experiences for students that will enable them to learn effectively and to motivate them to engage in the corresponding activities."

Indeed, a great deal of research showed that humans are better at remembering information that they create for themselves than information they receive passively (Anderson, Reder, and Simon, 2000; Bobrow and Bower, 1969; To, Lai, and Chung, 2013).

4. The Development of GreenXity Hong Kong

GreenXity is an interactive, immersive, simulation 3D game developed based on feature-based engineering software. It is designed to allow users to design their own sustainable campus using renewable energy, green technologies and low-carbon management measures. As its name implies, GreenXity has a wide range of buildings including commercial and residential buildings, hospitals, schools, cultural centers, parks, gardens, roads, and vehicles. Building types and distributions closely resemble

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what people can see in Hong Kong because GreenXity was created to simulate the situation in a typical Asian metropolis. To nurture green awareness among high school students, virtual school campuses were built based on the information provided by Hong Kong high schools. Each virtual school campus is equipped with a virtual environmental resource and education center in which students can explore the operational principles, functions, physical characteristics, environmental performance, and costs of various green technologies. In addition, numerous examples are provided so that students can see how systems have been utilized to generate electricity and to save energy, water, material resources, among others. Figure 2 shows GreenXity and the resource center of a virtual school.

Figure 2. GreenXity - the cover page (on the top left hand side) and the campus, equipped with an environmental resource and education center, of a virtual school.

4.1 Environmental Impacts of School Activities

A school, like all other man-made systems, unavoidably, adversely affects the environment during the construction, operational, and demolition phases of its buildings and facilities. During academic semesters, teachers and students make use of school facilities for teaching and learning. A school consumes a significant amount of electricity for lighting, space conditioning, and powering ICT infrastructure, and water for cleansing and gardening. On the other hand, the saving of 1-kWh electricity can reduce about 0.8 kg of CO_2-equivalent because Hong Kong's power companies use fossil fuels including coal and natural gas to generate electricity (Lai, To, Lam, and Lo, 2012; To, Lai, Lo, Lam, and Chung, 2012). A school also generates a large volume of solid waste including consumables and packaging waste in its offices and classrooms, and food waste from its cafeterias and canteens. Because some parents send their kids to school by cars, indirect impacts such as the consumption of gasoline and vehicle noise (To, Ip, Lam, and Yau, 2002) are produced. As Hong Kong is a densely populated city, some schools are located in the vicinity of major roads, roundabouts, and bus terminals, and are exposed to a very high noise level (Chung and To, 2011; To and Chan, 2000).

4.2 The Use of GreenXity for Raising Green Awareness - Hong Kong Low Carbon School Design Competition

A school-wise competition, called Hong Kong Low Carbon School Design Competition, was organized in 2012 that engaged students in using the green tech components of GreenXity and the interactive learning process. In the beginning of the Competition, the Organizer, a non-profit organization in Hong Kong, sent representatives including an author of this paper to schools in order to brief teachers and students about the aim of this competition, environmental impacts of school activities (as described in Section 3.1), and various features of GreenXity. Figure 3 shows that representatives were warmly received by teachers and students in schools.

Figure 3. School visits

After school visits, a number of high school teams made use of GreenXity to explore various green technologies and to test how various combinations of green technologies could reduce the environmental footprint of school activities. Table 1 shows some of the most popular technologies tested by students at that period of time. Green technologies and practices are broadly classified as renewable energy sources such as wind and solar power, energy saving technologies and practices, carbon offset, water saving, waste management and reduction, ecological protection, among others.

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Green Technologies/Practices	Objectives
Renewable energy sources	
- Micro/small wind turbine* (1.25-2.5m/<1.25m in dia.)	- Generate electricity using wind energy.
- Solar panel**	- Generate electricity using solar energy.
Energy saving technologies and practices	
- LED lighting	- Can save energy by around 80 percent.
- Using curtains	- Reduce cooling loads in hot summer days.
- Switching off air-conditioning units at 25.5^{o}C or below	- Avoid excessive electricity consumption.
Carbon offset	
- Green roofs and green walls	- Plants absorb CO_2 (also regulate temperature and protect biodiversity).
Water saving	
- Rain harvesting	- Collect rain water for gardening.
- Smart water taps	- Save water.
Waste management and reduction	
- Waste sorting and recycling	- Reduce the amount of solid waste.
- Non-disposal utensils in cafeterias and canteens	- Reduce the amount of solid waste.
Ecological Protection	
- Green roofs and green walls	- Enhance biodiversity.

* The measured noise level was about 62 dBA at 10m from a horizontal-axis type micro wind turbine or 46 dBA at 10m from a vertical-axis type micro wind turbine (Clohessy, Sharp, and Vorster, 2011).

** Grid-connected PV panels can save electricity significantly but their performance is affected by the shadow effect (Lam, Lai, Lo, and To, 2012).

Table 1. Green technologies and practices offered by GreenXity.

Student teams took their initiatives to modify their virtual schools by testing different green technologies and to visualize how those technologies reduce environmental impacts and to what degree. Each time, they updated their designs and the associated environmental performance in GreenXity. As the rules of the Competition included that (i) each team could not adopt more than a number of types of technologies, (ii) the total cost of the adopted technologies should not exceed a preset amount, (iii) and the space available depending on the school's physical size, student teams had to obtain an optimal design by learning from examples, discussing with their teachers and peers, and observing the trade-off between adopting an environmental technology to its alternatives. Besides, schools are located at different geographical locations. Hence, meteorological factors such as wind, sunshine, shadow effect, among others, have different influences on the performance of a certain type of environmental technology from one location to another.

As time passed, some high school teams decided not to participate in the Competition because of a number of reasons: students were busy in preparing school and public examinations, students were not ready for public presentation, students had other priorities in extra-curricular activities, etc. Approaching the deadline of the submission of student designs for Hong Kong Low Carbon School Design Competition, 40 student teams signed up the Competition and submitted their designs on or before the deadline.

The final of the Competition was held on 24 March 2012. The selected teams were chosen for the final because their designs had been evaluated by a panel of designers and environmental experts with the highest overall scores based on objective criteria including energy saving, water saving, materials saving, and the installation and operating costs of the systems installed, and subjective criteria including feasibility, technical innovation, creativity, and the quality of report. During the final, students in the form of groups, presented their designs, explained the reasons why certain green technologies and practices were adopted while others were not, and answered the queries made by the panel of designers and environmental experts. Indeed, each team had its own design and students thoroughly understood the limitations and advantages of each green technology/practice. Students could articulate the reasons why they chose certain technologies but not others. Among all given technologies, micro wind turbines, green roofs, and waste sorting and recycling were the top three popular facilities and practices adopted by student teams. Other green design elements including LED lighting, green walls, using curtains to screen off sunlight, and switching off air-conditioning units when ambient temperature fells below 25.5^{o}C, were also popular. Table 2 shows the percentage of teams adopted these designs.

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Green Technologies/ Practices	Percentage of teams adopted the design	Green Technologies/ Practices	Percentage of teams adopted the design
Renewable energy sources		Carbon offset and ecological protection	93
- Micro wind turbine (1.25-2.5m in dia.)	93	- Green roofs	88
- Small wind turbine (<2.5m in dia.)	68	- Green walls	
		Water saving	78
Energy saving technologies and practices	88	- Rain harvesting	
- LED lighting	88	Waste management	93
- Using curtains	88	- sorting and recycling	
- Switching off air-conditioning units at 25.5^{o}C or below		Others	78
		- non-CFC refrigerants	

Table 2. Green design features adopted by student teams.

Three student teams were awarded the first prize, second prize, and third prize of the Competition. Nevertheless, students from all teams indicated that they benefited from taking part in the Competition because obtaining green knowledge, developing communication skills, and experiences working as a team member are valuable to each of them.

5. Discussions and Conclusion

Sustainable development can only be achieved in long-run if (and only if) we and our next generations understand how our activities interact with the environment and decide to change our 'old ways' of doing things such as consumption and waste and to stop driving species out of habitats by urban sprawl and climate change. However, we cannot force people to change and should not spoon-feed young generations with information about what is the right (or wrong) thing to do. Hence, raising students' awareness about environmental impacts and sustainability is challenging.

Students in Hong Kong and other urban cities worldwide have a regimented schedule that does not allow them to experience nature or a rural lifestyle. In addition, the Hong Kong Education system has an emphasis on rote learning and this is not conducive to educating students on environment impacts, sustainability, and green issues. Besides, the content of sustainable development is conceptual challenging and covers lots of information. Having standardized teaching materials and supporting facilities are not enough. To overcome the shortcomings of passive learning, GreenXity and Hong Kong Low Carbon School Competition were conceived, developed, and implemented, allowing students and teachers to share and exchange useful information and news. Indeed, students and teachers indicated that using computer games as an educational tools increases the learning interest. The Hong Kong Government should provide more resources for game companies to develop more environmental games and clear instructions should be provided.

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