

Comparing pedagogies for plastic waste management at university level

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Abstract

Purpose – This article aims to compare the learning outcomes of gaming simulation and guided inquiry in sustainability education on plastic waste management. The current study targets the identification of success factors in these teaching approaches.

Design/methodology/approach – This study employed a quasi-experimental design with undergraduate participants who were randomly assigned to an eight-hour sustainability education class using either gaming simulation or guided inquiry. Pre- and post-tests on students' knowledge, attitudes, and intended behavior were conducted, followed by individual interviews to provide more detailed reflections on the teaching approach to which they were assigned.

Findings – In terms of knowledge acquisition and behavioral changes, the quantitative results suggested that the pre-/post-test in-group differences were significant in both groups. More importantly, a significant positive attitudinal change was observed in the gaming simulation group only. In the interviews, participants attributed effective knowledge acquisition to active learning element in class, while the characterization of cognitive dissonance triggered in the gaming simulation induced subsequent affective changes.

Practical implications – Activities in this program can be applied or modified to accommodate differences in other similar programs. The findings can also provide indicators to designs of similar programs in the future.

Originality/value – This article explores plausible factors (ideology and implementation) that contribute to successful sustainability education programs. Through comparison between gaming simulation and guided inquiry, elements for effective ESD learning in the pedagogical designs are discussed.

Introduction

Education plays an important role in the sustainable development of society (Bertschy *et al.*, 2013; Leal Filho *et al.*, 2015). To address the significance of such education, the United Nations Decade for Education for Sustainable Development 2004–2014 (DESD) was implemented, the ultimate goal of which was to empower learners in their values and behaviors towards achieving sustainable development. This was to be achieved through learning tasks that developed learners' abilities to think critically, to foresee future scenarios, and to make decisions in a collaborative manner (UNESCO, 2006). With more schools including education for sustainable development (ESD) in their curricula, ESD has emerged as a new area of research, particularly in higher education (Kopnina and Meijers, 2014; Thomas, 2014). Chalkley (2006) described higher education as contributing hugely to sustainability by equipping future leaders of society and business with knowledge, attitudes, values, and skills that lead to a sustainable future. Higher education graduates from different programs are entering different professional sectors and help achieve environmental sustainability if they are equipped with such a preference.

While most ESD studies have focused on theoretical directions and understanding of pluralistic concepts of sustainability, pedagogical research on the contextual application of the complex sustainable development concept remains underexplored (Tarrant and Thiele, 2016; Thomas, 2014). Thomas (2014) contends that, in ESD programs, only science-based knowledge is stressed, and that holistic sustainability concepts are rarely touched upon. Such kind of practice is unlikely to promote changes in students' values and behaviors in favor of a sustainable lifestyle. Segmented or unrelated teaching in different disciplines has been identified as one of the pitfalls of ESD. Sibbel (2009) also suggested that independent curricula of disciplines in higher education have hindered students from acquiring a "sustainability mindset."

Hence, this study attempts to fill the research gap by comparing two different teaching approaches, (1) gaming simulation (GS) and (2) guided inquiry (GI), for a holistic sustainability program in the higher education context. The effectiveness of these two approaches was evaluated based on their achievement of positive outcomes among participants. Information regarding how and why these approaches work was also gathered via retrospective qualitative interviews, providing useful details for further analysis.

Criteria of teaching approaches for ESD in higher education

Researchers have sought new forms of teaching that can adequately address the complexity of sustainability and the connections and interdependencies among the environmental, social, and economic aspects of sustainable development (Amador *et*

al., 2015; Leal Filho *et al.*, 2015). Owing to the complex and dynamic nature of sustainability, which emphasizes reciprocity between nature and society, the conventional one-way and segmented mode of teaching in higher education (such as didactic lecturing) may not be the best pedagogy for ESD (Tarrant and Thiele, 2016). The focus of classes should no longer be on a mono-disciplinary topic (usually concentrating on scientific knowledge) but one that can holistically address the multi-disciplinary nature of sustainability

The affective domain (values, attitudes, and behavior) has also been considered one of the critical elements of ESD. This view has been accepted by academics and adopted by various multinational summits and conferences (Buissink-Smith *et al.*, 2011; Leal Filho *et al.*, 2015; Shephard, 2008; Shephard *et al.*, 2015b; UNESCO, 2006). In addition to the well-known Bloom's Taxonomy on Cognitive Learning (1956), Krathwohl, Bloom, and Masia (1964) have proposed a Taxonomy of Affective Learning (from lowest to highest: receiving, responding, valuing, organizing, and characterizing) for the pursuit of affective learning outcomes (Shephard *et al.*, 2015b). Shephard (2008, 2015b) has also claimed that desirable ESD programs should seek to achieve higher-order affective and cognitive outcomes. In fact, with well-planned design, the two Taxonomies can intersect at higher-order stages. For instance, when learners infer the "hidden agenda" about an incident (i.e. "analysing" stage in Cognitive Taxonomy), this simultaneously helps learners to develop or reflect upon their value system (i.e. "valuing" stage in Affective Taxonomy) (Shephard, 2015). By introducing ethical principles (e.g. fair procedure, precaution, reversibility, and equity) in an undergraduate ESD course, Biedenweg and her colleagues (2013) argued the importance of equipping students with the ability and readiness to make ethical decisions for the sake of their professional and personal development.

In addition, effective ESD teaching approaches should encourage active participation, higher-order thinking such as critical evaluation, and personalized decision-making (Gottlieb *et al.*, 2013; Stern *et al.*, 2014). Barth and colleagues (2007) have reiterated that key sustainability competencies were better developed through experiential learning (e.g. active experience and on-going reflection), instead of passively receiving information.

Dialogue and discussion among stakeholders are crucial in consolidating what is learned (Amador *et al.*, 2015; UNESCO, 2006). This fits the social constructivist notion, which emphasizes how knowledge can be constructed via social interaction instead of simply being told by teachers (Leemkuil *et al.*, 2003). Yet, not all discussions can lead to fruitful learning. One of the keys to maximizing learning effectiveness may be to apply the concept of situated cognition, in which students participate in tasks to solve problems that are directly related to their real-world

experiences (Brown *et al.*, 1989; Brundiens *et al.*, 2010).

To satisfy all these criteria, it is necessary to identify teaching approaches that can encompass most, if not all, requirements for desirable sustainability education. We may not find an ESD pedagogy that will guarantee success in all areas, but still, it is worthwhile to gain insights into effective ways of directing learners' knowledge, attitudes, and behavior towards a more sustainable lifestyle. Hence, a quasi-experimental setting was adopted in the current study. The reasons for selecting gaming simulation and guided inquiry for comparison will be discussed in the following sections.

GS as an ESD teaching approach

Since the development of simulation and gaming, debates have been ongoing concerning how best to define and distinguish between “simulations”, “games”, and hybrid “simulation games” (Crookall, 2010; Dorn, 1989; Garris *et al.*, 2002; Wilson *et al.*, 2009). Simulations are usually defined as methods to represent certain real-world processes, often through the abstraction and conceptualization of complex real-world systems (Dorn, 1989; Garris *et al.*, 2002). Provided with a referent in reality, simulations are educational by nature. Opposite to the authentic mechanism in simulation, games are entertaining activities that may contain imaginary game characteristics such as a fantasy storyline, scoring or level increments, and challenging goal attainment (Garris *et al.*, 2002).

Gaming simulations literally combine key features of simulations with games, merging real-world representations and imaginary game features into a single tool (Dorn, 1989; Garris *et al.*, 2002). Specifically, a gaming simulation is, with particular educational objectives and game elements, an artificial but reality-resembling environment that allows participants to experience the concerned social system through a dynamic and sequential decision-making process (Klabbers, 2009; Kriz, 2003). Hence, the context of GS readily creates an excellent educational environment for participants to understand the interwoven nature of sustainability originating from the interplay between the economic, environmental, and social dimensions in the real world (Katsaliaki and Mustafee, 2015; Fabricatore and López, 2012). This can be the reason for the increasing ESD simulation games available in recently years (Katsaliaki and Mustafee, 2015; Wu and Lee, 2015). There are other features for GS to be a suitable ESD teaching approach:

- Fast-forward experience in a time-compressed environment. Participants can learn how their actions interact with the environment in a few hours, which would otherwise require years to observe in reality (Lu *et al.*, 2014).

- Multidisciplinary nature of GS and ESD. This can foster holistic understanding without the limits bounded by specific discipline (Crookall, 2010; Katsaliaki and Mustafee, 2015).
- Fun and safe atmosphere. This can motivate active participations among learners for problem identification, negotiations, and shared decision making (Katsaliaki and Mustafee, 2015).

More importantly, debriefing after GS is essential so that the participants are allowed to personalize their learning by interpreting the experience (in terms of cognition, emotion, social interaction, system process, etc.) they have just had in GS (Crookall, 2010; Kriz, 2010; Lederman, 1992). Through the sharing of observations, feelings, and reflections, participants may also be inspired among themselves (Powers and Kirkpatrick, 2013). Sometimes, instructors may help provide meaningful and/or alternative interpretations to trigger in-depth discussions (Goetze, 2015). The ultimate goal for debriefing is to help learners gain insights from GS that can be put into applications in reality (Kriz, 2010). Such learning process fits the notion of experiential learning that knowledge and skills are actively built up by the accumulation of experience through continuous reflections (Crookall, 2010; Kolb *et al.*, 2014; Kreber, 2001).

GI as an ESD teaching approach

Originating from constructivist theories, inquiry learning has been considered a desirable approach for instruction from elementary to tertiary levels (Banks and McGee-Banks, 1999; Farrell *et al.*, 1999; Jung *et al.*, 2015; Setty and Kosinski-Collins, 2015). It has been reported as a useful tool for education on sustainability, in training students to apply various generic skills, and to analyze complex environmental issues from political and social perspectives (Gilbert, 2004).

Inquiry learning requires students to learn actively by seeking solutions to identified problems. University students tend to prefer inquiry learning to lecturing as the former usually includes more active learning activities such as experiments. In the inquiry learning process, students mimic the practice of a scientist to generate knowledge, enabling hypotheses to be tested by experimental data analysis (Pedaste *et al.*, 2012). Students actively take essential roles in the learning process to discover new findings from the results.

There are four levels of inquiry—(1) Confirmation Inquiry; (2) Structured Inquiry; (3) Guided Inquiry; and (4) Open Inquiry, which ascend according to the degree of guidance from instructors (Banchi and Bell, 2008). GI was selected for the current study as it imposed a manageable challenge for the relatively mature undergraduate students to answer and explain a given question on their own. To achieve a fair

comparison between two approaches, open inquiry is not applicable in the current study with specific contents in the ESD program.

Plastic waste management as the topic for the ESD program

Since sustainability is a broad topic, for the sake of a clear and contained focus, plastic waste management was selected as the topic of the ESD program in this study. It was also selected due to its alarming global and local impacts.

Plastic waste management has been a global environmental challenge, provoking considerable international attention and concerns (Bing *et al.*, 2012; Velis, 2014). The characteristics of plastic (e.g., it is light, chemically stable, durable, and low-cost) make it an excellent raw material for making products (Hardesty *et al.*, 2015). With only 1.5-million tonnes produced in the 1950s, plastic production increased drastically to 257 million tonnes in 2007 and further increased to 299 million tonnes in 2013 (PlasticsEurope, 2015; Okumura *et al.*, 2014). This disturbing increase is expected to aggravate further with the economic growth in most developing countries (Guerrero *et al.*, 2013).

Ecological disasters have resulted from the high volume of plastic waste (mostly in the form of micro-plastic) that exists in the oceans (Fok and Cheung, 2015; Hardesty *et al.*, 2015). It is estimated that up to 12.7 million tonnes of plastic became marine debris in 2010 (Jambeck *et al.*, 2015). It is frequently documented that marine lives died from the ingestion of or entanglement in the marine debris. Nearly 700 marine species have been reported to be fatally threatened by marine debris, of which plastic accounts for 92% (Gall and Thompson, 2015). In addition to aquatic species, seabirds also suffer severely from the marine disposal of plastic waste (Hardesty *et al.*, 2015). Even worse, plastic debris can also transfer toxins to marine organisms, which accumulate along the aquatic food chain and eventually transfer back to humans (Hardesty *et al.*, 2015; Thompson *et al.*, 2009).

Researchers predict a tenfold increase in plastic waste entering the ocean in the coming decade if there is no amelioration in existing waste management infrastructures (Jambeck *et al.*, 2015). This threat is not only imminent in developing countries, but also in some metropolitan cities. A good illustration is Hong Kong, where landfill is currently the only waste treatment solution. Due to the limited capacity for landfill, solid waste treatment is increasingly raised as a concern within society, building tension between the government and residents living in areas close to landfill sites (Cheung *et al.*, 2015). This was exacerbated by the high labour and site rental costs in Hong Kong, as local recycling factories could no longer sustain their operations. More specifically, while the amount of plastic waste generated is increasing annually, the recycling rate cannot keep pace, particularly in recent years (Environmental Protection Department (EPD), 2015). The amount of plastic that is

recycled decreased by 84.6% from 1,577 thousand tonnes in 2010 to 242.7 thousand tonnes in 2013 (EPD, 2011; EPD, 2015). This implies that Hong Kong citizens should take on additional responsibilities when recycling plastic waste (such as cleansing and sorting), instead of relying too heavily on recyclers. Considering this situation, there is an urgent need to educate the public, particularly pre-service professionals in universities, to understand plastic waste management in a comprehensive way. In so doing, desirable behaviors in favor of a sustainable future may eventually be facilitated (So *et al.*, 2016; Morgan, 2012). In this comparative study, both quantitative and qualitative methods were employed to assess the effectiveness of the selected approaches in ESD.

The research questions are as follows:

1. To what extent would students' knowledge (K), attitude (A), and intended behavior (B) change in response to the two teaching approaches?
2. What are the factors contributing to the K, A, and B changes, if any, in response to the two teaching approaches?

The Program

An eight-hour ESD Program, with two teaching approaches, was developed to educate participants on the current situations and shortcomings of plastic waste management in Hong Kong. In addition, possible socio-political and technological solutions were discussed from multiple perspectives. Recommended skills and procedures for recycling plastic waste were also shared with the participants, with the ultimate goal of empowering sustainable decisions.

To ensure a fair comparison, the manpower used to lead each approach was even: One teacher with four trained senior-year undergraduate students (i.e., instructors). The designs of the two teaching approaches are delineated in the following sections. The learning objectives and key activities are summarized in Table 1.

Table 1. Highlights of the key activities used in the two approaches

Learning Objectives	Guided Inquiry	Gaming Simulation
(1) To learn the principles and current situation of plastic waste management in Hong Kong.	- Hands-on investigation at rubbish bins on campus - News clippings - Analysis of waste statistics from the government - Group discussion	- Invited seminars given by the “government officers” of the Plastic City - Taking exams in “school” - Creating advertisements for the “broadcasting company”

(2) To understand the application of the 3Rs concept (Reduce, Reuse, Recycle) in society, and their economic, social, and environmental consequences	- On-campus mini survey about plastic bag tax - Investigate the durability of daily objects such as raincoats and plastic bags	- Policy debate between “government” and “citizens” about tax on household waste & plastic bags - Introduction of reusable containers in the Plastic City.
(3) Plastic waste classification	- Plastic waste classification experiment	- Inter-district Plastic Waste Sorting Campaign
(4) To develop a positive attitude towards the sustainable use of resources (mainly plastic products)	- Presentations & debates	- Debriefing session

Design of the GS approach

The whole GS was designed to let students experience, in a short timeframe, the relationship between human overconsumption and plastic waste generation, as well as ways in which a society could respond to the problem. At the beginning of the class, students role-played in a simulated city called “Plastic City” (called “City” hereafter) with a background very similar to that of Hong Kong. All students began as new immigrants and were located in eight districts (i.e., groupings). The teacher and instructors acted as leaders of the City (such as the mayor, market owner, schoolmaster, etc.) to facilitate the development of the City.

The City operated in rounds, with six rounds (20-mins each) in total and each round representing a five-year period. In each round, all citizens could freely decide what to do at various “spots” (such as school, factory, shop, etc.) and interact with the instructors as well as other citizens. They had to work (i.e., complete tasks) in certain “spots” in order to earn the living they required to purchase food and accommodation before the end of each round. Different types of food, products, and accommodations were offered in the City. The more expensive these were, the higher the “prestige level” the buyers could acquire. The “prestige level” of each citizen was made public on the screen.

The screen also displayed the academic background of the citizens. They had to pass exams in the “school” on basic knowledge of plastic waste management. Questions of varying difficulty were designed; from true-false questions for “primary school,” multiple choice questions for “secondary school,” fill in the blanks for

“college,” to short questions for “graduate school.” Citizens with advanced academic backgrounds would be offered higher-paid jobs to motivate people to learn.

Various incidents brought about by the increase in plastic waste would then intervene. For example, the landfill site of the City (represented by an A4 paper box in the classroom) would be filled up with plastic bags thrown away by participants after shopping. In response to the situation, various activities such as voting for waste treatment facility (e.g. expanding the landfill or building an incinerator), invited guest talks (e.g. instructors/participants acting as the government officers/green group members) on plastic waste management, and recycling campaigns were introduced to facilitate collective decision-making among citizens.

At the end of the GS, a 30-minute debriefing was conducted for participants to evaluate their wasteful lifestyles in the City, with an ultimate goal to reflect upon their actual behaviors in reality. Guiding questions for debriefing were designed with reference to “Six Phases for Quality Debriefing” (Kriz, 2010, p.669-671). In addition, the instructor would explain the design of the GS corresponding to the learning objectives.

Design of the GI approach

According to the learning objectives, the eight-hour program was divided into different sub-sessions with one focused topic and one guiding question. Students were divided into working groups of five to six per group. Each group was led and facilitated by one instructor. Students had to actively seek the answers by performing various inquiry tasks: (1) on-site observation (e.g., searching for the recycling bins on campus), (2) hands-on investigation (e.g., conducting experiments to classify and categorize different kinds of plastics), and (3) data collection (e.g., first-hand: randomly interviewing students on campus and second-hand: conducting internet searches).

After conducting each task, students were given 30 minutes to discuss and analyze the collected data. They were then required to report their findings and share their ideas and thoughts with their peers. Open discussions were encouraged after all presentations, and groups with different viewpoints could further discuss or even debate controversial issues. Eventually, the teacher would summarize opinions and shared some of the prepared materials (as in the GS class) with the students.

Methodology

Subjects

A total of 60 students (Years 1-4) were recruited from one institute specializing in teacher education in Hong Kong. Participants were randomly assigned to two

groups, using one of the two teaching approaches (GS or GI). The students attended a four-hour session for two consecutive weeks (totaling up to eight hours). A total of 37 furnished questionnaires were returned from 23 participants in the GS group and 14 in the GI group. The total response rate was 62%. The demographic data of respondents are illustrated in Table 2. The statistics demonstrated that there were no significant differences between the two groups in the distribution of gender and grades.

Table 2. Demographic table of the students in the Program

	GS (N=23)	GI (N=14)	Sig ^a
Gender			
Male	7 (30.4%)	5 (35.7%)	0.739
Female	16 (69.6%)	9 (64.3%)	
Year of Study			
Year 1	6 (26.1%)	3 (21.4%)	0.693
Year 2	2 (8.7%)	0 (0.0%)	
Year 3	10 (43.5%)	7 (50.0%)	
Year 4	4 (17.4%)	3 (21.4%)	

^a χ^2 chi-square test

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Quantitative Data

Pre- and post-intervention questionnaires were used to collect quantitative data, investigating the effectiveness of the two teaching approaches in facilitating changes in knowledge (K), attitude (A), and behaviors (B). Non-parametric tests, such as a Mann-Whitney U test and Wilcoxon Signed-Ranks test, were performed using SPSS 21.

(i) Knowledge

The 25 questions in the knowledge test were categorized into three parts: (1) general knowledge of local waste management, (2) understanding of the 3Rs (reduce, reuse, recycle) concept, and (3) plastic waste classification.

(ii) Attitude

Twenty questions were developed to measure the students' pro-environmental attitudes towards waste management. These questions were based on the Attitude towards Recycling Scale (Larsen, 1995) and the self-developed attitude questionnaire tailored to the Hong Kong context (So *et al.*, 2016). The questionnaire used a five-point Likert scale, in which 5 represented the most and 1 the least positive

pro-environmental attitude.

(iii) Intended behavior

The intended behavior of students was measured by a series of questions using a 5-point Likert scale, where 5 represented the most and 1 the least prepared for pro-environmental waste management behaviors. The questionnaire (So *et al.*, 2016) investigated the disposition of participants to practice sustainable behaviors learned in the program, e.g., the “4 plastic recycling steps” and the 3Rs concept.

Qualitative Data

For the semi-structured interviews, 12 students were interviewed (6 from each teaching approach) to understand how and why the program had changed their K, A, and B. To ensure documentation of opinions from people with different test performances, interviewees were selected based on the percentile ranks of their knowledge-test performance: two interviewees from the top 33%, two from the medium 33%, and two from the lowest 33%.

Results

Enhancement of knowledge, attitude, and behavior after the program

The pre- and post-tests showed significant increases in the mean scores for both groups in the aspects of knowledge and intended behavior (Table 3). Students in the GS group showed a significant change in attitude towards recycling after the program, while those from the GI group did not. No significant between-group differences were observed in any of the three aspects. The results are summarized in Table 3.

Table 3. Summary of overall results in the two teaching approaches.

	GS (N=23)				GI (N=14)			
	Pre-test	Post-test	Dif.	Sig. ^a	Pre-test	Post-test	Dif.	Sig. ^a
K	4.91±1.76	19.44±3.45	14.53	0.000***	5.36±1.65	17.86±3.94	12.5	0.000***
A	4.02±0.34	4.11±0.37	0.09	0.035*	3.98±0.46	4.14±0.45	0.16	0.120
B	3.18±0.63	3.41±0.63	0.23	0.02*	3.08±1.01	3.41±0.94	0.33	0.011*

^a Wilcoxon Signed-Ranks test

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: The full scores for K, A, and B were 25, 5, and 5, respectively.

Improved general knowledge of local waste management

This section consisted of five questions testing participants’ knowledge of waste management in Hong Kong. For instance, questions about municipal solid waste

composition and waste management hierarchy were included. In Figure 1, both groups demonstrated significant improvements after the eight-hour program. For the GS group, the mean score increased significantly from 2.348 ± 1.152 to 3.957 ± 1.022 ($p < 0.001$). For the GI group, the mean score increased significantly from 2.714 ± 0.910 to 4.071 ± 1.28 ($p = 0.022$).

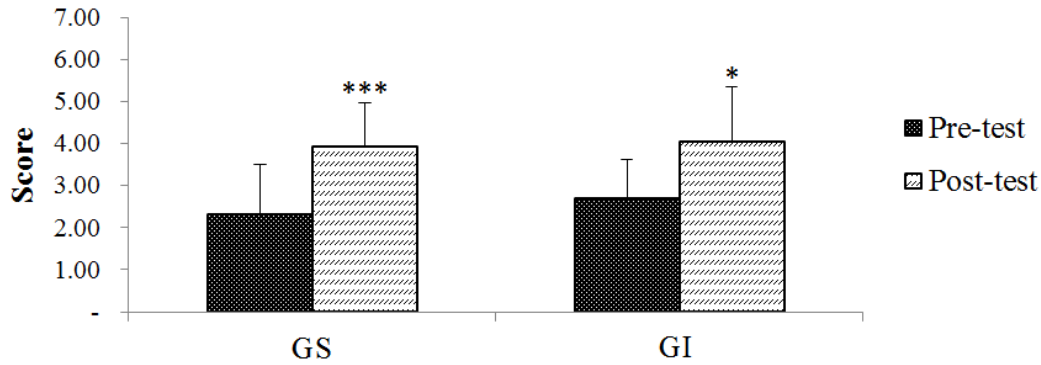


Figure 1. Pre- and post-test scores of general waste knowledge in the two teaching approaches.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: The full score for general knowledge of local waste management is 5.

Improved knowledge of the 3Rs concept

The six questions in this section evaluated participants' understanding of the 3Rs concept. Sample questions included “Are CDs recyclable?” and “What is the third of the four recycling steps?” Both groups demonstrated significant increments in their mean scores after the program (Figure 2). For the GS group, the mean score increased significantly from 1.391 ± 1.118 to 4.261 ± 1.389 ($p < 0.001$). For the GI group, the mean score increased significantly from 1.571 ± 1.016 to 3.714 ± 1.383 ($p < 0.001$).

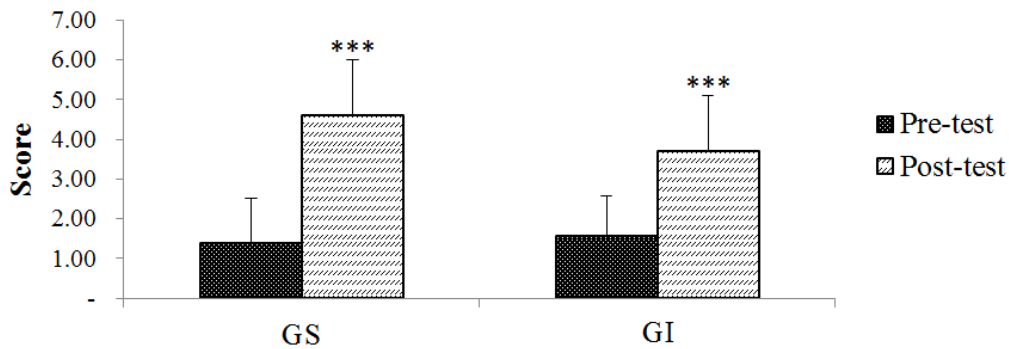


Figure 2. Pre- and post-test scores of the 3Rs concept in the two teaching approaches.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: The full score for 3R knowledge is 6.

Improved knowledge of plastic waste classification

This section inquired about participants' knowledge of common types of plastic waste, such as plastic bottles, food containers, and straws. In Figure 3, significant increases were observed in the mean scores of both groups. For the GS group, the mean score increased from 1.130 ± 1.791 to 11.174 ± 2.443 ($p < 0.001$), while for the GI group, the mean score increased from 1.071 ± 1.328 to 9.571 ± 2.338 ($p < 0.003$). A post-intervention knowledge performance test revealed significant improvement when classifying "Styrofoam takeaway box" in the GS group only. Other than this, both groups showed significant improvement in classifying the remaining 13 items.

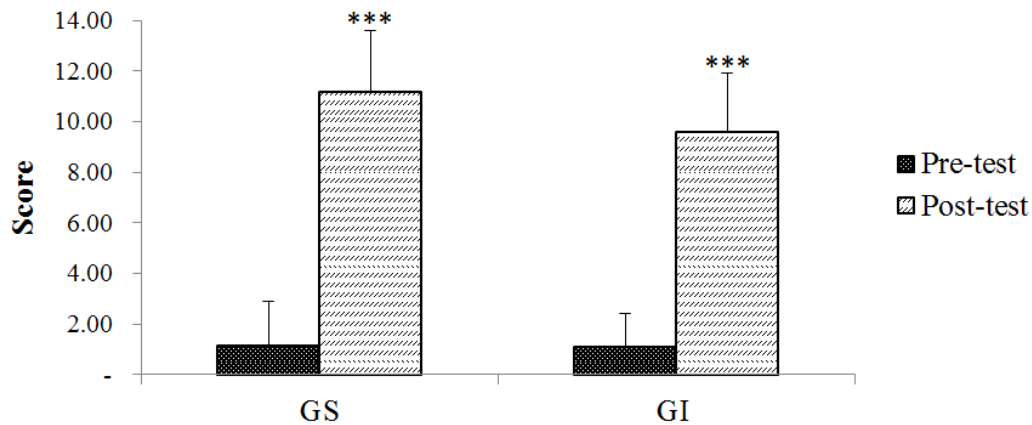


Figure 3. Pre- and post-test scores of plastic sorting knowledge in the two teaching approaches.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: The full score for plastic waste classification is 14.

The interviewees' responses supported the results derived from the quantitative data, revealing significant improvements in all three knowledge aspects. In Table 4, three sample statements from each group are highlighted. Almost all interviewees from both groups could remember the knowledge learned in the program (see statement 1). They generally attributed their knowledge acquisition to active and collaborative learning in the program. Five out of the twelve interviewees from each group mentioned that they were actively involved in the learning process, which motivated them to learn (see statement 2). Half of the interviewees mentioned the importance of group discussion in their knowledge acquisition process (see statement 3).

Table 4. Sample interview statements for knowledge

Key point	Statements from GS students	Statements from GI students
1. Knowledge acquired	<i>“I studied the plastic classification thoroughly when I was preparing for the ‘exams’ in the plastic city.”</i>	<i>“I remembered the plastic classification system better when I could be involved in the sorting task in person.”</i>
2. Motivation to learn (active learning)	<i>“I learned actively in order to win the game. I paid attention during the talk about plastic waste management.”</i>	<i>“The learning process triggered my curiosity to learn and I could understand better by finding out the answers on my own.”</i>
3. Group discussions foster learning	<i>“Group discussions strengthened my memory of knowledge because we had to think thoroughly before sharing.”</i>	<i>“In the group discussions, group-mates could help explain the details, which helped me understand the information better.”</i>

GS enhanced plastic waste recycling attitudes

The pre- and post-test results suggested significant pro-environmental changes in the GS group only. The recycling attitudes of the GS group improved significantly after the program, from 4.020 ± 0.340 to 4.105 ± 0.373 on average ($p=0.029$). A positive improvement was also observed in the GI group from 3.984 ± 0.461 to 4.143 ± 0.445 ; however, the result was not significant ($p=0.154$). The Cronbach’s alpha for the attitude test of the GS and GI groups were 0.87 and 0.89, respectively, indicating an acceptable internal consistency (George and Mallery, 2003).

Different interviewees’ views regarding attitudinal change

In the interviews, most participants mentioned that they were concerned about plastic waste management, whereas some from the GI groups had different concerns. For the GS group, all interviewees reported that their reflections upon waste management practices in Hong Kong were triggered most in the debating session when conflicts of values were obvious (see GS statement 1 in Table 5). In addition, the debriefing session at the end contributed to the affective learning purpose (see GS statement 2).

On the other hand, four out of six interviewees from the GI group reported that they were shocked by the unexpected chaos in plastic waste management on campus.

This feeling of unease served as a timely reminder that they must persevere in recycling waste in future (see GI statements 1&2). Some of their remarks are summarized in Table 5 below.

Despite the general agreement on attitudinal changes, some participants from the GI group claimed that their attitudes did not change significantly because they already possessed a strong pro-environmental attitude before joining the program (see GI statement 3).

Table 5. Sample interview statements for recycling attitudinal change

Key point	Statements from GS students	Statements from GI students
1. Session that triggered attitudinal reflections	<i>“Not in my backyard” thinking triggered my reflection. In the debate about landfill extension or incinerator building, people voted for the option that affected them the least without considering the environmental problems.”</i>	<i>“I cannot imagine there are so many recyclables in rubbish bins; we should recycle more.”</i>
2. Session that triggered attitudinal reflections	<i>“In ‘Plastic City,’ we bought as much as we could to enhance our social status without considering the environmental cost. In the end during debriefing, we could really experience how much waste we had generated.”</i>	<i>“In the recycling bin, the plastic inside was dirty and not separated, I think we need to do better so that the recyclers have an easier life.”</i>
3. No sig. change in attitude	N/A	<i>“I knew most of the situations and had been an environmentally-friendly person before I joined the Program, so I don’t think I changed a lot in attitude.”</i>

Positive intended behavioral change in both approaches

Students from both groups gained significant improvement in their intended behavioral change towards plastic waste recycling. The mean scores of both groups improved significantly; the GS group from 3.183±0.625 to 3.407±0.625 (p=0.043),

and the GI group from 3.076 ± 1.01 to 3.414 ± 0.939 ($p=0.015$). The Cronbach's alphas were 0.89 and 0.92 for the GS and GI groups, respectively, suggesting the high internal consistency of the test (George and Mallery, 2003).

The responses observed in interviews echoed the questionnaire findings. In addition to the intended behavioral change, participants reported that they genuinely practiced what they had pledged to do when answering the questionnaire. A number of interviewees mentioned several pro-environmental behaviors after attending the program. For example, they tried to recycle plastic waste according to the guidelines they had learned (see statement 1). Others claimed that they shared with their family members or friends the recycling steps, such as the importance of waste separation and ways to implement it (see statement 2).

Nevertheless, many of the interviewees were ambivalent and hesitated (due to factors such as availability of facilities and time cost) when considering how to treat their waste (see statement 3).

Table 6. Sample interview statements for sustainable behavioral change

Key point	Statements from GS students	Statements from GI students
1. Actual recycling behavior	<i>"I intentionally brought my plastic waste to the designated recycling bin on the 7th floor, which was far away from my room."</i>	<i>"I washed the plastic bottles before recycling."</i>
2. Sharing of knowledge with family and friends	<i>"I asked my mum not to throw away the plastic waste, and helped her recycle."</i>	<i>"I recommended that my friends use the designated plastic recycling bin for recycling."</i>
3. Difficulties in taking sustainable actions	<i>"I saw my brother throw away a lot of plastic waste, but I didn't have time to help or teach him how to separate it."</i>	<i>"If it was convenient, I would recycle."</i>

Discussion

The present study compared two teaching methods (GS and GI) in an ESD program on plastic waste management in a higher education institution. Regarding knowledge, both teaching approaches could significantly enhance the knowledge of local waste management, the 3Rs concept, and plastic waste classification. The

findings also suggested that both approaches were capable of imposing positive and significant changes on students' knowledge and intended behavior. In terms of attitude, the GS approach seems more effective in leading to significant changes when compared to the GI approach. This seems to be the only difference in the comparison of the two methods.

Although the two compared teaching approaches have distinct designs, underlying principles, and presentations, they may not be mutually exclusive to one another. As it is difficult to totally eliminate direct teaching component in one teaching approach, particular sessions in the GS may resemble tasks in inquiry learning. However, this does not suggest that pedagogical comparison is meaningless. Rather, it is essential to identify the underlying elements in the pedagogical design that can contribute to effective learning. Table 7 summarizes and compares the elements included in the two teaching approaches. It is noted that differentiations can be observed under the same element. For instance, the element "experiential learning" can be applied to both GI and GS. Yet, the former may suggest the concrete hands-on activities whereas the latter may refer to the conceptual and simulated activities. More importantly, through the comparison of the two teaching approaches, three key elements in the pedagogical designs (that have plausibly contributed to the changes in K, A, and B respectively) are suggested and discussed in the following paragraphs.

Table 7. Comparing the elements in the two pedagogical designs

Elements in pedagogical designs	Guided Inquiry	Gaming Simulation
Experiential learning	- Concrete experience - Hands-on activities using five senses	- Conceptual experience - Simulated activities in a created social system
Active learning	- Yes	- Yes
Collaborative learning	- Yes	- Yes
Self-learning	- Searching, collecting, and analyzing data	- Declarative knowledge
Creation of cognitive dissonance for higher-order affective learning	- No	- Yes
Role-playing	- No	- Yes
Presentation	- Conducted by learners	- Mostly conducted by teacher and instructors
Debriefing	- No	- Yes

Engaging in knowledge acquisition: Active learning

The interviewees from both groups (GI and 1st GS) attributed their learning

motivations to the active learning features in their received pedagogies. Typical responses were exemplified as follows:

“The learning process triggered my curiosity to learn and I could then understand better by finding out the answers on my own.” (GI interviewees)

“I learn actively to win the game. I studied hard for the exams in the school in Plastic City.” (GS interviewees)

This echoes the consent to appeal for the application of active (or student-oriented) learning in higher education (Chan *et al.*, 2015). By taking an active role in learning, the university students were found to be more motivated, achieved better academic performances, and understood the scientific process better (Armbruster *et al.*, 2009; Derting and Ebert-May, 2010).

Specifically in the GS group, all six interviewees recognized the effectiveness of the “school” counter in Plastic City. In the GS, considerable time was inevitably spent on the “gaming” aspect. Hence, the introduction of basic information that requires minimal understanding (e.g., data regarding HK waste and examples of each plastic classification) was reduced or even waived. Nevertheless, this was successfully compensated by a “school” exam for which participants eagerly studied this information autonomously in order to attain high-paying jobs in Plastic City. A positive correlation was observed between the “academic level” in Plastic City and post-test knowledge. According to the GS interviewees, the elevating difficulty levels of “exams” helped them remember the knowledge effectively in a fun way. Such active learning design demonstrated a highly effective strategy for learning in a fun environment during class without compromising the content.

Achieving higher-order affective outcomes: Cognitive Dissonance

Comparing the two teaching approaches, significant improvements in attitude were only reported in the GS group. In the GI group, participants were required to answer the guiding questions through various hands-on activities related to plastic waste management. Each group had to make observations, collect data, and interpret the findings. These processes formed the first two levels (i.e., Receiving and Responding) of the Taxonomy of Affective Learning (Krathwohl *et al.*, 1964), in so far as learners were presented with a new situation and participated in discussing it (Buissink-Smith *et al.*, 2011). Each group then presented their findings and conclusion to the other group for further discussion or debate. This activity falls on the third level of the Taxonomy, Valuing, in which learners had to explain their values and rationale. In case of dispute, students had to defend or adjust their own values by comparing and contrasting different ideas. This may enter the fourth level of the Taxonomy, Organizing (Shephard *et al.*, 2015b). However, such disagreement was

rarely observed in the GI group and, therefore, the students could only reach the third level during most of the program time.

In the GS group, deep reflection triggered during debriefing was regarded as the key element for attitudinal change, as exemplified by the following quote from one of the GS interviewees:

“In Plastic City, we bought as much as we could to enhance our social status without considering the environmental cost. I was so proud of my high “prestige level” (note: score in the GS) before the end of the GS. However, during the debriefing, I suddenly realized how much damage we had imposed to the wildlife.”

Different from many simulation games in which the players act as chief officers (e.g., Goetze, 2015; Rackaway and Goertzen, 2008), participants in this study played the role of normal civilians in “Plastic City.” In this instance, resemblance between the simulated situations and the actual world were strong. During the debriefing session, participants were asked to explain why they had bought extravagant but unnecessary products. They began to ponder upon their held beliefs about prestige and their unlimited want of material goods. For instance, when they reviewed their votes against the more environmentally preferred “incinerator” so as to spend less “simulated money,” some participants expressed remorse and regret over their decisions because they used to believe that their habits were already environmentally friendly.

Such drastic inconsistency between their beliefs (i.e., acting sustainably) and their behaviors in GS (i.e., acting unsustainably) aroused critical reevaluation of their held values. This discrepancy, according to the Theory of Cognitive Dissonance (Festinger, 1957), creates a feeling of dissonance and psychological discomfort, which can only be ameliorated by behaving in new ways that are congruent with their new beliefs. This process falls into the fifth and highest level of the Taxonomy of Affective Learning, Characterization, in which learners can generalize their own set of values (Shephard *et al.*, 2015). Hence, the simulated experience and the debriefing session were critical in driving attitudinal changes among participants.

In fact, Cognitive Dissonance Theory, which was proposed in the 1950s has been supported by recent neuroscience studies (Jarcho *et al.*, 2011; Vincent *et al.*, 2009). These scientists elucidated, with neuro-images, Festinger’s claims (1957) that changes in attitude depend on the magnitude of dissonance aroused. In addition, such attitude change can be engaged within seconds within a decision making process (Jarcho *et al.*, 2011). This evidence challenges the general (yet inconclusive) assumption that increased duration of ESD programs can contribute to more significant learning outcomes (Stern *et al.*, 2008; Rickinson, 2001). The studies provide an alternative

perspective to understand the notion that a significant change in attitude can be achieved by introducing strong cognitive dissonance in a short period of time. Therefore, it is convincing that attitude change is possible within a relatively short (eight-hour) program. In fact, previous studies have recorded significant changes in attitude after programs of similar or shorter duration (So *et al.*, 2016; Bogner, 1998; Farmer *et al.*, 2007).

Encouraging intended behavioral changes: Action Competence

A plethora of conceptual models proposed in previous decades has suggested the complexity involved in identifying factors that can produce pro-environmental behaviors (Kollmuss and Agyeman, 2002). In their review, Kollmuss and Agyeman (2002) concluded that knowledge and attitudes are indirect factors leading to desirable environmental/sustainability behaviors. These are of much less importance when compared to internal personal traits as well as external infrastructural and socio-economic factors. However, other researchers have expressed different viewpoints. Jensen (2002) argued that particular types of knowledge were critical to kick-start people's willingness to take pro-environmental actions. It is agreed that scientific facts do not of themselves lead to action, but causal analyses and procedural knowledge (collectively known as action competence) can certainly strengthen the linkage between knowledge and behavioral change (Jensen, 2002; Jensen and Schnack, 1997).

In this program, emphasis was placed on both the causes of and solutions to plastic waste problems in Hong Kong. In the interviews, most participants attributed their pro-environmental behavioral change to the comprehensive understanding of plastic waste management. Typical statements include “*I will try my best to conduct “clean recycling” after understanding the difficulties faced by our recycling industries*” and “*Now I know how to classify the plastic waste according to their types and I will do it*”. This suggested a plausible reason why a mere knowledge increment could still lead to intended behavioral change in the GI group, lending support to Jensen's claim. Yet, uncertainties exist due to the possible differences between intentions and actual behavior. Given that only participants' behavioral intentions were collected (with a limited number of actual behavior examples reported in the interviews), the effects of external factors (i.e., barriers that deter pro-environmental actions) were not fully reflected. Nevertheless, the process of arousing awareness and experiencing a simulated situation (from causes and effects to practical solutions) of sustainability incidents could be a key to triggering behavioral intentions.

Implications for ESD teachers in higher education

The results were encouraging in that both cognitive and affective outcomes for university participants significantly improved in a relatively short period of time (i.e., eight hours). Pedagogical design played a key role in achieving this. Instead of didactic teaching, allowing students to explore and lay hands on a problem can personalize experience and result in better learning outcomes. This ensures that no learning content is compromised and what is learned is valuable to the participants. In addition, it is always useful to keep the interesting material for class time, leaving basic understanding for self-study. However, this is easier said than done. Creating a game-like class environment may be beneficial, as illustrated in the case of GS. ESD teachers may endeavor to provide a learning environment conducive to the exchange of ideas and reflections to encourage higher-order affective outcomes. There is seldom an absolute right or wrong when it comes to sustainability issues. Through discussion and debate with peers, students have the opportunity to clarify and rationalize their values and attitudes. The case of GS created an interesting interface of characterizing the discrepancy between “me in simulation” and “me in mind,” and the impact was significant.

Despite all the advantages mentioned, there exist some challenges to teachers who adopt these two approaches. First, a great deal of effort is required to design the instructional content. Although GS does not require any computer programming techniques, the development of the plot with meaningful and engaging tasks underlying the GS could prove challenging and time-consuming. It is, on the other hand, relatively simple to apply GI. Teachers need only break down an issue into different sub-topics and design the corresponding questions and tasks.

Another challenge is the change in teachers’ roles. They are no longer the authoritative person in the classroom who may only focus on presenting the course materials clearly, but acting as facilitators with multiple sets of skill instead. For instance, they have to be keen observers to provide constructive feedbacks during the learning process, asking critical but not intimidating questions to trigger in-depth reflection, exploring options by suggesting alternative perspectives, and sometimes addressing unprepared questions raised by learners (Clapper, 2014; Grasha, 1994; Kolb *et al.*, 2014). These can present a major challenge for long-in-service teachers who are accustomed to the traditional lecturing style.

Conclusion and future research directions

To address the increasing importance of equipping students with sustainability competence in higher education, innovative and effective ESD programs shall be designed and remodeled. Adopting gaming simulation and guided inquiry, the current study has provided empirical evidence of positive learning outcomes as well as

analysis for the three key elements in the pedagogical design. Both groups demonstrated significant improvements in knowledge and intended behavior by employing active learning activities that promoted action competence. With designs that triggered cognitive dissonance among students, higher-order reflections in the affective domain were successfully facilitated. Hence, GS demonstrated a significant result in changing participants' attitudes in favor of plastic recycling within the eight-hour program.

The current research has a number of limitations that demand further exploration in future research. First, although the participants in the two approaches have a similar background (local undergraduate students) and no significant differences were noted between them based on the pre-test, there are confounding variables (such as ability to learn, attention span in the 8-hour training, readiness to adapt values and beliefs) that cannot be controlled. With the small and unbalanced sample size in the current comparison, the quantitative results are exploratory and require further assessments. Second, students' affect (especially behavior) may not be fully assessed by a hypothetical written pen-and-paper test (Shephard *et al.*, 2015a). It is worth conducting a longitudinal study in future to collect participants' actual behaviour over time. Third, as mentioned earlier in discussion, one teaching approach can contain multiple elements. It is challenging to single out the effect of specific elements, especially when these elements may have complex interactions with one another (Garris *et al.*, 2002; Stern *et al.*, 2014). Hence, depending solely on the retrospective interview response from learners may not be able to critically evaluate the effectiveness of particular elements in the pedagogical design. Despite the mentioned limitations, the effective pedagogical elements identified in the GS and GI may serve as a foundation for future ESD pedagogical studies in higher education. More ingenious research design (such as design-based research) may be promising in isolating the concerned elements for further analysis and fully exerting the potentials of the identified ESD pedagogies.

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