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How High's the Water, Mama? A Reflection on Water Resource Education in Singapore

K.N. Irvine *National Institute of Education (Singapore)*

Tricia Seow *National Institute of Education (Singapore)*

Leong Ka Wai *Ministry of Education (Singapore)*

Cheong Sze Ing, Diana *Public Utilities Board, Singapore's National Water Agency*

Introduction

Iconic American singer-songwriter Johnny Cash recalled in song a boyhood experience of watching his parents monitor flood conditions at their 1937 Dyess, Arkansas, home by counting the number of front steps the water had risen; 1 step = 1 foot (0.305 m):

How high's the water, mama?

Five feet high and risin'

In introducing his 1959 Columbia release, Five Feet High and Risin', Cash noted (AZLyrics, 2000-2015):

> *My mama always taught me that good things come from adversity if we put our faith in the Lord.*
>
> *We couldn't see much good in the flood waters when they were causing us to have to leave home,*
>
> *But when the water went down, we found that it had washed a load of rich black bottom dirt across our land.*
>
> *The following year we had the best cotton crop we'd ever had.*

Although the event occurred half a world away and decades ago, the themes of the song resonate with the Singapore of today (in addition to being a pertinent lesson for our Geography curriculum). Chang and Irvine (2014) noted Singaporeans have become particularly sensitised to flooding as the result of the costly events that occurred in 2001, 2006, 2007, and 2010. Singapore certainly has a more advanced flood monitoring system than Johnny Cash's boyhood Arkansas, with the Public Utilities Board (PUB) maintaining a network of 166 water level sensors in drainage canals and rivers that update every 5 minutes and more than 40 of these sites also have CCTVs (Figure 1). The fact remains, regardless of the technology, communities are interested in monitoring flood levels as an element of risk management. In becoming a nation, Singaporeans faced a great deal of adversity. Just as Johnny Cash's family weathered the adversity of flooding to reap the benefits from a bumper crop of cotton, so too has Singapore weathered adversity, to the extent that according to IMF statistics its per capita GDP (adjusted by purchasing power parity) was some $28,000 greater than the U.S. in 2014.

Water is essential. It plays an

irreplaceable role in the ecological hierarchy, ranging in spatial scale from protein folding, to terrestrial ecosystem primary production, to biome distribution (Rosenzweig, 1968; Sala et al., 1988; Chaplin, 2001; 2006; Fisenko and Malomuzh, 2009). It is a driver of the rock cycle by catalysing chemical and mechanical weathering (White and Blum, 1995; Matsuoka, 2001). It has a psychological significance in human well-being (White et al., 2010) and can positively or negatively impact human health (Bartram and Cairncross, 2010). Many have discussed the strategic importance of water, although there is disagreement as to the likelihood of water wars (Wolf, 1998; Swain, 2001; Allan, 2002; Amery, 2002; Poff et al., 2003; Yoffe et al., 2003). Certainly, the transboundary nature of a resource that flows from upstream to downstream, not recognizing political borders, present complicated challenges to management (Harris et al., 1987; Mackenzie, 1997; Bernauer, 2002; Keskinen et al., 2007; Irvine et al., 2010). The characteristics of flow, temporal and spatial variability, and interactions between human and physical systems very much make water a topic of interest in geographic studies.

Water is an issue of national security in Singapore (Tortajada, 2006; Lee et al.). Despite its small land area, which limits catchment size, Singapore has a goal of water self-sufficiency by 2061. This goal is being pursued through the PUB's Four National Taps strategy that is discussed in detail by Irvine et al. (2014)(see also, PUB, 2010a). The Four National Taps focus on NEWater, desalination, and runoff collection and storage in the 17 existing reservoirs located throughout the island, with decreasing reliance on imports from Malaysia. The move towards meeting the self-sufficiency goal has required Singapore to develop a sophisticated, "closed-loop" approach to water management that has become a model, certainly regionally, if not globally (Tortajada, 2006; Ong, 2010; Chen et al., 2011; Irvine et al., 2014). Technology must be integrated with policy to effectively advance approaches in water management and in this area, Singapore also has excelled through public-private partnerships (Olds, 2007; Irvine et al., 2014) and research at local universities. In fact, Lux Research Inc. recently named the National University of Singapore and Nanyang Technological University as the one and two ranked universities globally in the area of water research, with important focus on deslination, reuse, and membranes (Lux Research, 2013). Tortajada and Joshi (2013) observed that the Singaporean school curriculum has played a central role in educating future generations with respect to water and the environment and most certainly this is one piece of the puzzle that helps to explain the country's innovative approach to water resources management. Yet, Ghosh (2015) reflects on the ability of the fishing community in the East Kolkata (India) wetlands, who have no formal education in ecology, to sustainably manage their ecosystem. He poses the question "how do they know what they know"? and if the answer is "through experience", then the logical follow up is "how do they learn through experience"? How did a good ol' boy from rural Arkansas understand the link between floods, overbank deposited sediment, and crop productivity? The point here is that education extends well beyond the classroom and that informal and nonformal education can enhance the well-being of civil society in both developing and developed countries (Caron and Carr-Hill, 1991; Nath et al., 1999l; Colardyn and Bjornvold, 2004; Kedrayate, 2012; Ololube and Egbezor, 2012).

Given the importance of water and

education to Singapore, and certainly their connection with Mr. Lee Kuan Yew, the first Prime Minister of Singapore, we felt that it was appropriate to reflect on water resource education trends in Singapore to mark SG50. In particular, we discuss how the Singapore curriculum and the nonformal education sector present water resource concepts and examine why these approaches to education have been successful in supporting Singapore's rise to international recognition. Clearly, this is a broad topic with many actors and to make the discussion manageable, we focus on secondary school curriculum developments for Geography since 2006, trends in water resource education theory and practice in the Geography programme at National Institute of Education (NIE), Nanyang Technological University (NTU), and nonformal education programmes offered through the PUB. Before embarking on these discussions, it is important first to provide a brief background to the history of water resources development in Singapore. This following section is abstracted from Irvine et al. (2014) and Chang and Irvine (2014).

Background to the Water Resource Challenges Faced by Singapore

The beginning of an independent Singapore republic was marked by the visionary leadership of Mr. Lee Kuan Yew, Singapore's first Prime Minister (1965-1990) (Oei, 1998; Ang, 2013). Low (2011) asserts that Lee's focused initiatives to "green" Singapore have made good business sense by reducing pollution and cutting business costs. The "Garden City" was aptly named as its well-developed network of linked greenways and parks evolved from Prime Minister Lee's Tree Planting Day programme (Tan, 2006). Joshi et al. (2012) documented the steps towards the successful clean-up of the Singapore River between 1977 and 1986, emphasising that Mr. Lee's vision required close coordination between government agencies and different sectors in Singapore and a holistic approach to urban development, environmental management, sustainability, and economic opportunity.

The PUB was established in 1963, initially to oversee the provision of electricity, water, and piped gas (Khoo, 2009). After a significant involvement with the Singapore River restoration, which also prompted the development of separate storm and sanitary sewer systems, the PUB relinquished its mandate to manage electrical supply in 2001. Thus, marked the beginning of the Four National Taps water management strategy.

Two water agreements between Malaysia and Singapore were signed in 1961 and 1962, the first of which expired in 2011, with the second expiring in 2061. The current (second) agreement still provides up to 250 mgd (946,00 cubic meters per day (10.95 m^3s^{-1})). This water enters Singapore via pipeline at the Causeway between Singapore and Johor, Malaysia.

Singapore and Malaysia have a long history of water import agreements that stretches back to 1927 and a new round of water negotiations began in 1998 that were linked to economic packages focusing on recovery from the Asian financial crisis (Tortajada and Pobre, 2011). By 2003, Singapore had begun to look seriously for alternative water sources, including import from Indonesia, and ultimately the negotiations with Malaysia ended without agreement (Tortajada and Pobre, 2011). With the expiry date of 2061 for the second agreement looming, this has become the *de facto* planning horizon for Singapore to advance and diversify its technologies as it moves towards the goal of water self-sufficiency.

In addition to water import, the three remaining national taps are NEWater, desalination, and runoff from local catchments. Five NEWater plants now provide 60 mgd (273,000 cubic meters per day) which meets 30% of Singapore's water demands (Chew et al., 2011) and the PUB expects that by 2060 NEWater will meet 50% of Singapore's demand (PUB, 2010b). NEWater is produced from the country's wastewater that is first treated in secondary-level treatment plants and then passed to the NEWater plants for microfiltration, reverse osmosis treatment, and ultraviolet treatment. NEWater is used by Singapore's high tech industries that require high quality water and also is blended back into the surface water reservoirs. Singapore has two seawater reverse osmosis plants. The older plant produces 30 mgd (136 000 m^3/d) and meets about 10% of Singapore's water needs (PUB, 2010c). A second and larger desalination plant with a capacity of 84 mgd (318,500 m^3/day), was opened in September 2013. Together, the two desalination plants can meet up to 25% of Singapore's current demand (PUB, 2010d). Stormwater runoff is the fourth tap and is now captured from two-thirds of Singapore's land area and stored in 17 reservoirs throughout the island for subsequent use. Furthermore, all major estuaries have been dammed to create reservoirs, and the PUB intends to capture water from remaining streams near the shoreline, which will increase Singapore's water catchment area to 90% by 2060 (PUB, 2010e).

As discussed by Chang and Irvine (2014), an important test of the resiliency of Singapore's water system came in January and February, 2014. In the 61 days between 14 January to 16 March 2014, Singapore experienced an unusually dry period where the overall rainfall was 0.2 mm at the Changi Meteorological Station (NOAA Satellite and Information Service, 2015). The National Environmental Agency (NEA) called it the driest February since 1869 (Straits Times). Annual mean rainfall in Singapore is approximately 2,343 mm and February (the driest month) normally is 160 mm. The same drought also impacted Malaysia leading the government there to impose water rationing to 300,000 households in the Federal Capital of Kuala Lumpur and the adjacent state of Selangor, as well as another 50,000 households in Southern Johor (AFP, 2014). Despite imported water from Malaysia being one of Singapore's Four National Taps, the smaller city-state did not have to resort to water rationing. Indeed, the environment ministry assured the public during the dry spell that 55% of the country's demand could be met by the water produced at the country's own desalination and NEWater treatment plants "regardless of the amount of rainfall", which affords Singapore "a safety margin" (Straits Times). The NEA did issue a dry spell advisory which encouraged the public to adopt water conservation measures, while the PUB sent circulars by 8 March 2014 to 25,000 non-domestic customers advising on water conservation measures (NEA). Nevertheless, Singapore was able to cope with the drought, coming through relatively unscathed and this demonstrates water system resiliency.

Of course on the flip side, given the amount of rainfall that Singapore typically experiences throughout the year, localised flooding is a concern. Furthermore, the use of stormwater runoff as a municipal water source necessitates a balancing act for Singapore. The country wants to capture the maximum runoff practical, but also needs to balance the capture with concerns about localised flooding and quality of the runoff. In part, this issue has been addressed by the PUB's aggressive

implementation of Low Impact Development (LID) technologies, such as raingardens, impervious pavement, rain planters, green roofs, and constructed wetlands (Irvine et al., 2014; Chang and Irvine, 2014). In addition, through an expanded and improved drainage tile and canal network, the PUB has reduced localised flooding from about 3,200 hectares in the 1970s to 36 hectares today (PUB, 2010f).

Water Resource Education Trends in the Secondary Curriculum

The new Lower Secondary Geography Syllabuses for Express and Normal Academic (NA) Courses were implemented at Secondary One from 2014 (MOE, 2014). The previous syllabuses followed a systematic structure revolving around five themes. They were implemented at Secondary One in 2006, with a review of the syllabuses which started at the end of 2010. This review process is vital in ensuring a quality curriculum that achieves its intended teaching and learning goals. The new syllabuses are structured using an issue-based framework around two major themes, namely 'Environment and Resources' for Secondary One and 'Urban Living' for Secondary Two.

Based on the theme of "Environment and Resources", one of the issues that Secondary One students examine is Water Shortage, on both the local and global scale. Organisational framework aside, the key content and concepts in the 2006 and 2014 syllabuses remain largely similar. In the first theme on 'Environment and Resources', students are introduced to the biophysical environment that supports life on Earth. Students learn how natural resources are exploited and managed. More importantly, they examine how these resources can be used in a sustainable manner, as in the case of water issues in Singapore.

In the 2014 syllabus, Geographical Inquiry, adapted from Roberts (2013) is used as a key pedagogy in class and in the field. Roberts (2013) drew reference to how students learn to reason and how to argue, and the necessity for them to "understand how geographical knowledge claims are related to explanation and evidence" (p. 78). Such reasoning and arguing skills based on interpreting evidence are key to develop critical and inventive thinking, a 21st century competency that the Ministry of Education (MOE) seeks to develop in students (MOE, 2014). Roberts (2013) also reflected upon professional development activities and creating a culture of inquiry-based learning which were successfully trialled with teachers. Such a culture of inquiry is what the MOE hopes to inculcate in classrooms, to mould students into active contributors by taking the initiative to pose questions which could possibly lead to new insights and generate interest in the topic on Water Shortage. In this section, we look at the water education theme in Singapore's Geography curriculum, with a specific focus on the current curriculum that was implemented in 2014 and uses Roberts (2013) inquiry approach, which represents a significant change to the 2006 curriculum.

Curriculum review process in 2010

The 2006 syllabus underwent a mid-term curriculum review process in 2010 to understand teachers' concerns about the 2006 syllabuses, and to ensure that the curriculum achieves its intended teaching and learning goals. The review included an external scan of overseas syllabuses, including those of Australia, Hong Kong and United Kingdom to help in scoping the syllabus content. In addition, Ministry of

Education Curriculum Planning and Development Division (MOE CPDD) conducted Focus Group Discussions (FGDs) with teachers and students, surveys with school teachers and interviews with four external experts. The intention was to gain feedback from the "ground" with the aim of exploring possible new angles for an improved syllabus for Lower Secondary Geography.

The review suggested that several overseas geography syllabuses had changed to include the use of issue-based frameworks to help with the scoping of content. Singapore teachers also remarked that an issue-based framework would enable students to be exposed to a range of geographical issues as well as sufficient depth in each area. This provided a strong basis for adopting an issue-based approach for the 2014 syllabus.

Teachers also strongly felt that environmental issues should be included in the curriculum due to its relevance to students' lives, with a recommendation of including more current local and global examples to help students appreciate the relevance of the topics. This led to the inclusion of Water Resources as an issue to be studied in the 2014 curriculum, with detailed elaboration, for greater relevance to students' learning. This was reinforced by interviews with external experts such as PUB.

Lower Secondary Geography syllabus (2014)

With the findings of the 2010 curriculum review, changes were proposed and subsequently effected in the 2014 syllabus, including the adoption of an issue-based framework whereby students would acquire an understanding of Geography through the study of significant environmental issues confronting Singapore and the world. Using such an approach, the content was scoped to provide sufficient breadth and depth for students to understand each issue.

While the structure of the syllabus has been changed, the sub-topics relevant to the issue of Water Shortage as well as the study of water supply in Singapore were retained in the 2014 syllabus. A key difference is that there was more elaboration of content on NEWater as a way to increase Singapore's water supply, as well as water conservation efforts by the PUB such as the ABC (Active, Beautiful, Clean) Waters programme launched in 2006 and 'Friends of Water' outreach programme. Such elaboration is found in the 2014 textbook by Brown et al. (2014, pp. 169 - 171). An example of a page is shown in Figure 2.

The 2014 curriculum also focuses on conservation efforts acknowledging water's necessity to human life and as an important resource to various industries around the world. It stresses the need to conserve water through checking personal usage to ensure sustainability. The curriculum was intended to encourage students to value water as a precious resource which needs to be protected and used wisely, particularly given Singaporean's tendency to take the ready availability of water for granted.

According to MOE (2014), the inquiry-based learning introduced organises each issue of investigation around five main guiding questions as follows:

- What is the issue?
- Which part(s) of the world is/are affected by the issue?
- Why is the issue located there?

- How does the issue affect human society and natural environment?

- How should the issue be managed?

The questions serve as the organisational framework of the syllabus, using questions instead of statements as a framework , as was done in 2006 (Table 1).

As seen in Table 1, in the 2014 syllabus, the issue of Water Shortage is unpacked systematically through the five broad guiding questions which are aligned to the geographical inquiry approach. Such an inquiry learning approach was adapted from Roberts' (2013) who saw how learning is more effective when students are encouraged to question, investigate and think critically about issues affecting the environment and people's lives, now and in the future. The issue is also designed with an accompanying field-based learning with inquiry elements, termed Geographical Investigation (GI). This was intended to extend students' knowledge beyond water supply and conservation issues, to a field-based appreciation of how human activities can affect the quality of water. This is particularly important given Singapore's closed-loop approach to water management.

How High's the Water Mama? Revisited

In addition to the Water Shortage theme questions outlined in Table 1, the question of too much water is explored in the Urban Living Theme (Floods – How Can Cities Prepare for Floods?). Under this theme, lower secondary students will explore questions including: which cities are prone to floods? Why are these cities more prone to floods than others? How do floods affect people living in cities? How should cities prepare for floods? These are important questions, and while Singapore is well beyond counting the number of inundated steps to monitor flooding conditions, other issues of uncertainty have arisen, with respect to climate change, increasing frequency of extreme rainfall events, and sea level rise. Irvine (2013; 2015) discusses the challenges to design and plan for urban drainage to manage flooding conditions when traditionally such designs are based on the assumption of climate stationarity; yet in many areas, including Singapore, we are experiencing increasingly frequent, high intensity storms. The O-level Geography syllabus explicitly considers the question of increasing weather extremes. The issue of rising sea level impact on Singapore's coast has been explored as an academic topic of interest (e.g. Ng and Mendelsohn, 2005; NUS student project), but coastal change and sea level rise also are explored as part of the O-level Geography syllabus that examines the question, Why are Coastal Areas Valuable?

Feedback on Curriculum Development

From feedback gathered by CPDD during school visits last year, the issue-based approach has received positive feedback as students now find the content more relevant and interesting since they can connect better to real-world issues. Teachers also reflected that students have been better able to develop enduring understandings about issues.

By slowly building a culture of inquiry in classrooms, students learn more effectively about how water is produced and sustained by both environmental and human processes. More importantly, by giving students the opportunity to carry out GI at actual field sites, they are able to observe for themselves how water resources can be used in a sustainable manner in Singapore. This could have

great potential in developing students' social-emotional competencies in relation to water resources and the larger landscape of Singapore.

Water Resource Education Trends in Geography at National Institute of Education, Nanyang Technological University

This section focuses specifically on the Geography degree programme offered at the National Institute of Education (NIE), an autonomous institute within Nanyang Technological University (NTU), primarily because one of NIE's mandates is preparation of pre-service teachers through the BA (Education) and the PGDE (Postgraduate Diploma in Education) programme. The NIE programmes naturally fit in the context of curriculum trends discussed in the previous section and PUB outreach discussed in the next section. Clearly, NIE does not represent all opportunities for water resources training in Singapore's higher education system. As noted in the Introduction, for example, NTU and NUS programmes are conducting world-leading research in the water resources field. The NUS Geography Department offers water-related courses such as *Water and the Environment, Terrestrial and Coastal Systems, Ecological Systems, Urban Climate, Sediments and Sedimentary Basins, Environmental Conservation and Urban Tropical Ecology in SE Asia, Coastal Management, Advanced Hydrology and Catchment Management, Advanced Geomorphology, Climate Change Processes, Impact and Responses*, as well as several field-based courses. Of the five polytechnics in Singapore, three offer water-related diploma programmes: Republic Polytechnic – Environmental Science; Singapore Polytechnic – Environmental Management and Water Technology; and Temasek Polytechnic – Environment and Water Technology.

General Structure of the Geography Programme at NIE

The Geography Programme at NIE seeks to provide a broadly-based geographic education that will enable future teachers at all levels (primary, secondary, A-level) to competently address the broad range of 21st century competencies, as defined by the MOE, and to successfully deliver an in-depth geographic education to Singaporean students. As such, in the area of content, our BA students are required to take four courses at the 100 level (introductory physical, human, and geographic techniques courses as well as a course that specifically focuses on Singapore), six courses at the 200 level (second year, two in physical geography, two in human geography, and two geographical techniques classes), three courses at the 300 level (third year, with at least one in each of physical and human geography), and three courses at the 400 level (fourth year, including a final year project, geographies of sustainability, and a geographic thought class). In addition to the content courses, the students must take at least 30 credits (approximately 10, 3-credit courses) in teaching techniques and pedagogy, as well as an introductory 5-week in-school observation and two in-school practicums (a 5-week and a 10-week experience).

AAG401 *Geographical Methods and Fieldwork* is a capstone course required of all BA students and gives them experience in developing a research proposal, conducting fieldwork to collect the data, and submitting a minimum 10,000 word final report. It is quite analogous to the senior thesis exercises in North America, with the exception that the fieldwork must be conducted overseas. The course has

been held in numerous locations, including India, China, Malaysia, Vietnam, Australia, and the U.S.

Signature Pedagogies – The Current Trends

Shulman (2005) suggested that signature pedagogy involved professional training which addresses ways of thinking and practices central to the profession and which often is provided through apprenticeship. We promote two signature pedagogies in the Geography programme, one that builds on the tradition of fieldwork in geography and the other which is newly emerged, the Sustainability Learning Lab. Both focus on what it means to be a geographer and provide our students with experience in "how geographers think", with the goal of promoting thinking skills.

Fieldwork in the Geography Programme

Most of the research related to fieldwork suggests that the benefits to students' learning occur in the cognitive and affective domains. Within the cognitive domain, researchers have found that fieldwork brings students into real world settings and situations which contextualise and render visible the abstract, theoretical material taught in the classroom through experiential learning (Dummer et al., 2008; Mcguinness and Simm, 2005). Smith's (1999) survey showed that teachers agreed that fieldwork was important to allow students to comprehend concepts learned in the classroom. Other researchers also confirm teachers' positive perceptions of fieldwork as a learning tool (Fletcher and Dodds, 2004; Fuller et al, 2006; Scott et al., 2006). Fieldwork effectively conjoins cognitive processes with affective learning with the former directly and the latter indirectly affecting student learning outcomes (Kern and Carpenter, 1984; Smith, 1999; Boyle et al., 2007). For instance, McKenzie and White (1982) showed that active geographical fieldwork had positive impacts on long-term memory structures compared with passive fieldwork or no fieldwork because of "key episodes" - active and colourful events that have structural links to cognition, and which produce deep learning (Herrick, 2010). Harvey (1991, p. ii) pointed to fieldwork's value within the purely affective domain as well, "producing self and subject motivation through inter-alia novelty or milieu self-concept enhancement, productive role-modelling and changing students' scripts for learning".

Fieldwork in both human and physical geography content classes has always been emphasized in the programme at NIE, but since 2012 and the addition of three new content faculty, these efforts have been bolstered to the point that nearly every class includes at least one field exercise. Several of the curriculum studies classes (e.g. QCG524; ACG421) also focus on how to effectively teach in, and about, the field. Not surprisingly, many of the physical geography classes have a fieldwork component that focuses on water, either in relation to geomorphological processes, urban and rural ecosystem assessments, or water quality evaluations (Figures 3 and 4).

As noted previously, AAG401 also requires the students to conduct fieldwork in an overseas setting. Class size is such that two sections are offered and led by two different faculty, one focusing primarily on human geography and the other focusing primarily on physical geography. In this sense, students will specialise in either human or physical geography, but in both sections, elements of physical and human geography are

explored, with differing emphasis. Certainly, the theme of water has become a strong focus for both the human and physical geography trips in past years (Figures 5 and 6).

We strongly believe the international fieldwork is a valuable experience for our students, giving them a perspective on environments quite different from Singapore, but about which they may teach in their own classrooms. The true value added of an international experience is quite difficult to quantify. Qualitatively, we can draw on two recent AAG401 case studies as an (imperfect) assessment of the value of international fieldwork. In the first case, the class spent a semester preparing for physical geography fieldwork at three locations in Thailand: Chao Phraya River aboard a live-on, traditional teak barge; Karen Hilltribe Village near the Thai-Burma border at Maesot; and coastal studies at Hua Hin. Unfortunately, because of the political protests in Bangkok, two days before the group was to travel NIE canceled the trip. As such, the students quickly had to regroup and conduct research projects in Singapore. As part of the course assessment the students were asked to write a reflection about their experience and specifically address the question of whether they felt an international field experience was of value. Of the 23 submitted reflections, 15 (65%) explicitly stated an international field experience was preferable to a local field experience, while 1 student questioned whether an international field experience should be required. A number of students (13) noted that international and local field experiences had both positive and negative aspects and, philosophically, accepted the situation. Various reasons were given as to why an international field experience was desirable and the results are summarised in Table 2.

Some students expressed very strong feelings about not going on the international field experience:

> On a personal note, I have always wanted to major in Geography when I was in secondary school. This dream came true when I was offered the Crossover degree programme at NIE. The fact that I am going to go on an overseas field trip for my graduation module proved too much to be true. I never thought that I will be getting this chance to experience life as a geographer, like a once in my lifetime opportunity. However, this dream of mine still did not materialize in the end. AAG401 loses its essence in fulfilling a geographer's experience; it now becomes just another assignment at NIE.

Many students felt the international field experience would provide them with a more enriched experience that would make them better teachers:

> To be effective educators, teachers have to first be knowledgeable about world related issues and having a personal connection to global problems, such as water scarcity and water cleanliness, it would allow educators to convey the knowledge to the students more effectively...These skills [international experience] ultimately allow teachers to be able to carry themselves more confidently.

Another student tied the experience to MOE learning outcomes:

> By going overseas, students/researchers/undergraduates get to observe and immerse themselves in a culture that they are not used to, making them more culturally aware. In a globalised world of today, it is

> important that students become culturally sensitive and globally aware of the people living in other countries. This is especially important for student teachers who would one day lead their own students for a Geographical Inquiry field trip to other countries. One of Singapore's desired outcomes of education is "be able to collaborate across cultures and be socially responsible" (Ministry of Education Singapore, 2010). Another one of Singapore's desired outcomes at the end of post-secondary education is "be proud to be Singaporeans and understand Singapore in relation to the world" (Ministry of Education Singapore, 2010). In order to better understand Singapore in relation to the world, it is necessary that students are exposed to the world first.

The three principal benefits identified by students for conducting AAG401 locally were: i) enabled them to learn even more about an already familiar place (43% of the students); ii) more convenient for data collection and a more in-depth data collection programme was possible (30% of the students); and iii) savings on personal expenses (13% of the students). The single student not in favor of a required international field course noted:

> It is of my opinion that staying in Singapore to do a final year undergraduate research would prove to be as valuable as doing it overseas….. I think we ought to question the necessity of conducting field research overseas if the same scope of research work can be covered in Singapore…. Another issue to consider is the financial difficulties that some undergraduates might have to face if they were to fulfil the obligations of completing an overseas research project. It is also unfair to assume that all NIE geographers are able to accumulate their savings in years 1 and 2 to prepare for an overseas field trip.

The second case study represents the physical geography group that traveled to the U.S. in 2015 (New York City for two days and then Buffalo, NY to sample in the Buffalo River watershed and eastern end of Lake Erie). In addition to the fieldwork, a series of guest lectures was organized that included presentations from the U.S. Army Corps of Engineers (federal water agency), Erie County Department of Environment and Planning (local government water agency), and Buffalo Niagara Riverkeeper (citizen not-for-profit dealing with water issues). Each student was asked to keep a daily reflection log as part of their assessment and submit it at the end of the field experience, with results being summarised in Table 2. The structure of the reflection assignments was not the same for 2013 and 2015, so results in Table 2 must be considered with caution since there was some subjective interpretation in summarizing the discourse. Nonetheless, Table 2 might be interpreted as showing that while many students who were unable to participate in the overseas experience (2013) recognised the value of such experience, an even greater proportion of students who were able to participate in the overseas experience (2015) recognised the value. The authentic research experience and bonding aspects of the field course clearly was valued by many students. Equally important, in the case of the U.S. trip, 6 Muslim girls participated and all were unanimous in their surprise at how warmly they were welcomed. Said one:

> This trip has been really wonderful with so many adventures and meeting such great people. I could not have asked for a better group of people to travel with. The entire trip to the US

> has been a wonderful experience. I never thought I would enjoy it so much. Prior to the trip I was skeptical and thought the people in US would be very cold towards me and my muslim friends. But it really turned out the opposite and the people of NYC and Buffalo made my trip worthwhile.

This type of global exchange and dialog is invaluable in promoting understanding and appreciation for social and cultural diversity, as well as diversity in water management approaches, as discussed in the next.

As a follow up exercise during one of the post- U.S. trip class meetings two questions were discussed: what do you think are the major differences in water resource management between the U.S. and Singapore?; and How do you think knowing about these differences will impact your teaching strategies and content? The students quickly identified obvious differences in water management, for example that Singapore is top-down whereas the U.S. is more bottom-up and involves the public in decision-making to a greater extent. The students also were interested in how private land ownership in the U.S. impacts policy and management as compared to public land ownership in Singapore. The students were quite reflective on the value-added of the U.S. trip for their teaching. At least one felt the experience would not impact her teaching, except to provide "photos and stories". Others felt that by looking at different water management approaches, they understood water management issues better, which will translate into deeper discussions in their classes. This idea was expanded upon by a couple of students, one who thought the trip also broadened her horizons as a person which may impact how she taught civics and CCE courses, while another said she would be teaching about NEWater and she could now better contrast this approach to water provisioning with other approaches from around the world. A number of students noted that the size of the study watershed and lake gave them a new appreciation of scale and interpreting scale from a map and the diversity of the landscape better helped them visualize and understand processes (fluvial, coastal, and their interactions). Finally, many of the students noted that it would have been easier to conduct fieldwork and research in Singapore because they are familiar with the landscape and systems here. By conducting an overseas research study and recognizing they cannot simply "run back out to the site" the students felt they needed to be better prepared in advance, but it also made them "think on their feet" more effectively to solve problems.

Sustainability Learning Lab

The Sustainability Learning Lab (SLL) in the Humanities and Social Science Education (HSSE) Academic Group at NIE was established to provide a focus and framework for existing and on-going education and research initiatives. The primary objective of the SLL is to foster knowledge around sustainability by actively engaging through teaching, research and fieldwork and community participation. The SLL is meant to be both a virtual and real lab space. Integration of SLL concepts and technology will be done through pre-service teacher courses and graduate level classes for the Masters in Humanities Education (as summarised in Table 3). It is expected that in-service training workshops also will be offered.

One of the signature elements of the SLL is the establishment of field centres located throughout Singapore. Each field centre will have its own focus and provide its own unique learning opportunity. The

field centres will cover aspects of both human and physical geography and have a particular focus on geospatial data collection. The inaugural field centre will be located at the Jurong Eco Garden (e.g. Figure 3), which is adjacent to NIE and is under the purview of the Jurong Town Council. An MOE Edulab grant recently obtained by HSSE will support the acquisition and installation of a YSI datasonde to continuously monitor dissolved oxygen, turbidity, chlorophyll *a*, conductivity, pH, and temperature in the constructed freshwater swamp cell of the Eco Garden as well as a meteorologic station to log temperature, humidity, atmospheric pressure, wind velocity and direction, net all wave and shortwave radiation, and rainfall intensity. All data will be transmitted and stored on a server housed at NIE where both real time and historical records will be freely accessible for participating schools in Singapore.

The virtual lab part of the SLL will be in the form of a website and data portal. Also supported by the Edulab grant, it is envisioned that the SLL website will be simple to navigate, yet informative and a site for free exchange of geospatial and time series data related to sustainability. Initially, we have identified five topical themes (Figure 7) pertinent to sustainability and that reflect current curriculum content in Singapore. These five topical themes, Water in an Urbanizing World, Climate Change, Liveable Cities, Comparative Urbanism, and Ecosystem Services, are a preliminary, and not exhaustive, set of themes that might be included in Version 1 of the website. New themes will be added over the course of time, in response to emerging issues and curriculum revisions. Connecting the five topical themes and serving as underpinning for the website is the Geospatial Data page. All geospatial data will be visually represented using simple online mapping tools and the data also will be downloadable, free of charge. GIS functions such as overlay, buffer, and interpolation, will be provided for users to conduct simple analyses. In addition to base maps, on-site, historical, and real-time data can be mapped using the available tools. The YSI and meteorological data from Jurong Eco Garden also will be accessed through the website.

PUB's Schools Outreach Programmes: Nurturing a New Generation of Friends of Water

PUB's mission is to ensure an efficient, adequate and sustainable supply of water for Singapore. Aligned to the mission, PUB's schools engagement strategy is to place water stewardship high on the educational agenda, designing programmes that are aligned to the syllabus, therefore ensuring that the water topic is revisited every two to three years during the course of each student's formal education (PUB, 2015).

For over two decades, PUB has listened closely to the needs of students, educators, and the MOE as PUB engages the education sector. In the 1990s, PUB embarked on water conservation engagement campaigns to schools by conducting school talks and establishing a public education centre with exhibitions to promote water conservation; these campaigns were well-received by educators (Tortajada et al., 2013). During this time, MOE also organised community involvement programmes to encourage students to join activities related to water and resource conservation, which further reinforced the importance of water conservation amongst students (Tortajada et al., 2013). Resulting from PUB's engagement efforts, a key insight gleaned is that it is imperative to tell the Singapore

Water Story using an authentic learning approach by making more local case studies available, and developing place-based or kinaesthetic learning activities to facilitate knowledge retention. By doing so, the concept of water stewardship resonates better with students.

Syllabus-aligned Water Education Programmes

In 2009, MOE and PUB collaborated to systematically include water as part of the environmental education in the humanities syllabus. It was during this time that PUB gradually developed an array of schools outreach programmes with inputs from PUB's engineers, biologists, policy planners and public communication professionals. The programmes were then rigorously pilot tested with schools, MOE curriculum planners and community partners to incorporate educational pedagogies and content that are relevant to subjects' syllabus. In line with the MOE's goal to develop 21st century competencies in students, PUB's schools outreach programmes are designed to keep students well-informed of the larger context surrounding water resource management such as climate change, urbanisation, population growth and the criticality of good governance (PUB, 2015).

Between 2009 and 2015, a series of new programmes were made available for level-wide, cohort-wide schools outreach from preschool to tertiary levels. Two PUB-MOE Water Education Forums held in 2012 and 2014 brought educators and students to interact with PUB's internal experts and provided the opportunity for educators to network with PUB to find out more about areas of work such as stormwater management and monitoring water from source to tap, that are relevant to subjects' syllabus.

PUB's schools outreach programmes have gained traction with schools and the community. There is a growing interest amongst schools to join PUB as "Friends of Water" (FOW), an initiative launched in 2006 to recognise and inspire community stewardship of Singapore's water resources. The growth in schools FOW is in tandem with the increased take-up rate of schools outreach programmes. Currently, 67% of the pool of 321 FOW stewards are schools who have either adopted a water-centric programme or a waterway site. The high adoption rate amongst schools is a healthy indicator of the growing sense of ownership amongst the community of Singapore's water resources. The key schools outreach programmes targeting the different levels from primary to tertiary segments to raise awareness for water stewardship are outlined in the following sections and summary of the programmes is provided in Table 4.

1. Time to Save Assembly Skit

Launched in 2013, the 'Time to Save' water conservation awareness programme is aligned to MOE's Primary 3 Social Studies syllabus and inculcates the value of cherishing and conserving water resources to protect the environment. During the skit, the interactions between PUB's water hero, Water Wally, and other characters such as Professor Save and Water Waster, call out water wasting behaviours and illuminate good water saving habits (Figure 8). The skit has incorporated a shower dance to create excitement amongst the student participants and promote message recall (Chua, 2013). The impact of prolonged dry spells on Singapore's environment and water resources is also highlighted to reiterate the need to cut unnecessary water usage at home and in school.

About 50% of Singapore's domestic water consumption is attributed to showering and washing under the sink. The follow-up activity after watching the skit is aimed at targeting the behaviour to reduce shower time to under 5 minutes. In order to promote social interactions while proliferating water conservation messages to families and neighbours, students are tasked with the follow-up activity of tracking and keeping their showering time to under 5 minutes for a one-week duration, and to encourage their family members, neighbours and friends to do the same (PUB, 2013). To date, more than 107,000 students from over 100 primary schools have participated in the programme.

2. NEWater Scientist Programme

As described earlier, NEWater is a Singapore success story and the pillar of Singapore's water sustainability. With desalination and reclamation of used water, water resources are managed within a closed water loop that is Singapore's water cycle (PUB, 2012). Targeting Primary 4 students, the NEWater Scientist Programme (Figure 9) promotes an understanding of how technology is used to overcome Singapore's water challenges. NEWater Scientist Programme's immersive learning experience is made possible with role-playing and use of technology gadgets that capture students' imagination. Students put on laboratory coats and hard hats to role-play as NEWater scientists. Using the iPod Touch gadgets, students navigate the PUB's NEWater Visitor Centre (NVC) to discover and answer quizzes about NEWater, leveraging on their fascination with technology to promote learning (PUB, 2011). The programme broadens students' knowledge, prepares them to learn about the water cycle covered in the Primary 5 Science syllabus, and is also relevant to Social Studies, Character and Citizenship Education syllabus. This programme, available at the NVC, has attracted participation from 37,000 upper primary students across 110 schools.

NVC is co-located with the Bedok NEWater plant, allowing young NEWater scientists the opportunity to witness PUB officers performing their duties at the real-time supervisory control and data acquisition (SCADA) systems. At the conclusion of the programme, students also are provided the opportunity to directly taste test NEWater. Said a primary school level NEWater Scientist Programme participant: "From this programme, I am inspired to be a water chemist, to find out new ways to have more taps so that we have more supply of water."

3. Managing Stormwater in Singapore

Singapore receives abundant rainfall especially during the monsoon seasons. In the past 30 years, Singapore has experienced more intense and frequent rainfall events. The growth of urban areas has also resulted in greater stormwater peak flows from developed areas into canals; there are pockets of low-lying, flood-prone areas when intense storms coincide with high tides (PUB, 2014).

PUB's "source-pathway-receptor" approach looks at catchment-wide solutions to achieve higher flood protection (PUB, 2014). This is a newly available workshop designed primarily for Secondary 2 Geography students to complement their textbook learning about what causes flash floods in Singapore's context, and find out more about the "source-pathway-receptor" approach. Hands-on experiments with the stormwater management model help students learn better (Figure 10). This programme is also

open to tertiary students interested in this topic.

4. Youth Water Ambassador

Targeting uniformed groups and student leaders, the Youth Water Ambassador Programme engages youths to come together to collaborate and explore the possibilities to act and contribute towards water sustainability. At the workshop, youth leaders engage in debates, role-play and consider issues from multiple lenses as policy makers or members of civil society (Figure 11). Youth leaders are also provided with seeding ideas so they can start leading their own water advocacy initiatives.

5. Active, Beautiful, Clean Waters (ABC Waters) Learning Trails

The ABC Waters Learning Trails programme has been immensely popular with schools and has inspired 22 other community-initiated trails customised by community partners to their own needs. Launched in 2011, the ABC Waters Learning Trails target lower secondary students, and complements the secondary geography syllabus which promotes the ABC Waters Programme as well as the ideal of water stewardship. The trails are also relevant to biology, history, and Character and Citizenship Education subjects. To date, the trails have brought more than 61,000 lower secondary students from more than 137 secondary and integrated programme schools, out of the concrete classroom, into the living labs of Singapore's outdoor waterways and reservoirs. In addition, 22 pre-university and tertiary institutions found the programme meaningful for their students and have participated in the trails.

Currently, there are 10 learning trails located across Singapore and include: MacRitchie Reservoir, Alexandra Canal, Jurong Lake, Kallang River @ Bishan-Ang Mo Kio Park, Bedok Reservoir, Lorong Halus Wetland @ Serangoon Reservoir, Sengkang Floating Wetland @ Punggol Reservoir, Lower Seletar Reservoir, Yishun Pond and Marina Reservoir. At each trail, students enjoy fascinating stories of these unique sites as they appreciate biodiversity, heritage, water quality and sustainability design features (Figure 12). Through the trails, students learn about values as well: why collective action is important to keep our public spaces and waterways litter-free, and to ensure prudence in water consumption.

An estimated 31% of the schools who have participated in the ABC Waters Learning Trail made progress to conduct water advocacy-type of activities by spreading water messages beyond their schools to the community. There are examples of many other ABC Waters Learning Trails walks organised by the community for the community. A few commendable examples include - Hong Kah North grassroots' "ABC Waters Project Walk" initiative to bring residents of Hong Kah North on walks to 14 ABC Waters sites from June 2015; the first-of-its-kind kayaking trail at MacRitchie Reservoir that was jointly developed in 2014 by CreativeKids Pte Ltd and the Singapore Canoe Federation (Figure 13); Hwa Chong Institution's student leaders have led students from Canossian School on a hearing impaired trail using visual aids.

Former national athlete and Singapore Environment Council's Green Champion, U.K. Shyam facilitated an ABC Waters Learning Trail @ Marina Reservoir in 2014. After leading the trail, U.K. Shyam opined "the [ABC Waters Learning Trail] trip is also meaningful because it takes students away from traditional textbook learning to a real world setting where they

can see all the theories they learned actually manifesting in reality. At the end of the trail, I could see that the students had developed a strong sense of responsibility to the environment, something that normal classroom-based learning often cannot cultivate."

Significantly, the water quality testing component of the ABC Waters Learning Trails captured the interest of MOE curriculum planners. As part of the Secondary One Geography syllabus, one of the three geographical investigation field studies options is to conduct water quality testing at Singapore's waterway sites. The parameters tested include turbidity, pH, dissolved oxygen, and temperature of the water samples collected. Students are prompted to explain if the water collected directly from the reservoir is suitable for drinking purposes before educating them about the process of water treatment from source to tap.

The feedback from educators and students alike has been very encouraging. Said one teacher, "I think that the most interesting activity that the children participated in is the water quality test where they actually have a hands-on experience on checking the quality of water by conducting the ph level as well as the dissolved oxygen of the water." Another teacher added this, "The Learning Trails Programme definitely benefitted me as well as my students. And hoping by getting more students to participate in this Learning Trails Programme it will have the snowball effect where they can actually bring home the message that water is a very important natural resource for Singapore."

ABC Waters Learning Trails takes a train-the-trainer approach. Training workshops are given to empower passionate educators and students who are water advocates to be trained as facilitators/guides for the ABC Waters Learning Trails. This made the trails expansive in mileage. Besides schools, other organisations have also been working with schools to create their own trails. Said a Girl Guides Singapore student ambassador who led another school group on a trail at the Marina Reservoir, "After leading the trail I feel very satisfied, because I didn't know by doing the trail I could be so accomplished. I didn't feel it was hard and I am hoping for more of this to happen."

6. Singapore World Water Day

The United Nations has designated the 22nd of March to commemorate the importance of water sustainability. For Singapore, building water security and developing community stewardship of water resources has been integral to our nation's growth. Hence, Singapore World Water Day is a nation-wide celebration by the community, for the community to build a relationship with water and conserve, value and enjoy water. Every person is encouraged to contribute to and commemorate Singapore World Water Day in their own way (Figure 14). This year, more than 400,000 people all over Singapore celebrated World Water Day.

In celebrations throughout the month of March, the community has stepped forward for the water cause and supported PUB's call for everyone to conserve water. Water self-sufficiency is part of the late Mr. Lee Kuan Yew's legacy. Singapore World Water Day is a platform to encourage partnerships with its pool of FOW stewards, who have identified opportunities to work together and promote greater outreach, extending their sphere of influence to reach a network of other individuals and organisations promoting the water sustainability cause. There have been many schools who opted

to run ABC Waters Learning Trails for residents or other community groups during the Singapore World Water Day. For instance, in 2015, River Valley High School students facilitated the ABC Waters learning trail at Jurong Lake for delegates from Sino-Singapore Tianjin Eco-city, whilst Pei Hwa Secondary School and NParks have collaborated to lead a guided trail for the community and harvest pandan at the Sengkang Riverside Park.

Lessons Learned

PUB's schools outreach programmes are a means to achieve the goal of water stewardship. Attitudinal and behavioural changes "takes two generations to make people aware of any specific issue and two more to entrench the message" (Tortajada et al., 2013). Whilst schools outreach programmes may effectively increase the level of awareness students have about the preciousness of water and the importance to stretch this resource through water conservation, changing behaviours and making waterwise behaviours stick for the long-term to effectively manage reduction in water demand, pose a greater challenge. This is why sustaining public education on water remains important, and requires a collective action.

PUB's 3P partnerships (organisations and companies from the People, Private and Public sectors) across community stakeholder groups are important in jointly raising the level awareness to conserve, value as the community enjoys this precious water resource. Water stewardship and developing a commitment amongst students to effect behavioural change and a sense of water usage mindfulness well into their adulthood, where they grow up to become the new generation of Friends of Water, stepping forward to lead, to initiate water innovations or to drive water usage mindfulness underscores all of PUB's schools outreach programmes.

Conclusion

Johnny Cash was quite remarkable in his ability to transcend generations and musical genres. Part of his appeal was his ability to tell stories that were relevant to everyone. Likewise, the water story is pertinent to everyone. Johnny Cash could be both traditional and forward-thinking. The education system in Singapore is globally renowned and its attention to water resource issues reflects elements that are both traditional and forward-thinking. The roots of Singapore's modern water management system were squarely planted early in Singapore's independence and including efforts such as the clean-up of the Singapore River. The emphasis on field-based inquiry in the Secondary School curriculum and at NIE really is traditional Geography and yet it is a tradition that the discipline had moved away from by the 1990's. Perhaps the renewed interest in field-based, authentic experiences represents a new, forward-thinking chapter of an old theme. The value of both formal and nonformal educational approaches under the education for sustainable development rubric has been highlighted by a number of researchers (e.g. Haigh, 2006; Tilbury and Wortman, 2008; Brundiers et al., 2010; Wals and Keift, 2010). Most certainly water education in Singapore has been forward-thinking in integrating and scaffolding multidisciplinary and transdisciplinary elements at all levels, from primary through civil society and this type of creative thinking bodes well for the future of Singapore.

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Appendices

Table 1 Comparison of Water Resource Material Presentation, 2006 vs 2014 Syllabus

2006: Water Resources	**2014: Water shortage – Will our taps run dry?**
• Water as a scarce resource	• What is water shortage?
• Reasons for the rising demand for water	• Which locations in the world are facing water shortage?
• Responses to the rising demand for water ▪ Increase price of water ▪ Increase water supply	• Why does water shortage occur? ▪ High demand ▪ Low supply
• Case study of water supply in Singapore ▪ Same content as above + local examples e.g. Four National Taps	• How does water shortage impact people and countries?
	• How can Singapore avoid water shortage? ▪ Four National Taps ▪ Conservation efforts
	• Geographical Investigation: How clean is our waterway or water body?

Table 2 Frequency of Students Explicitly Commenting on Benefits of Overseas Fieldwork, AAG401 (as a per cent of total class) *

	Singapore/Thailand Fieldwork, 2013 (n=23)	U.S. Fieldwork, 2015 (n=24)
Provided an enriched educational experience that was "more authentic"	48	61
Provided a unique and valuable bonding experience with their cohort and future colleagues	30	74
Makes for a better teacher in a connected world	22	39
Improves teacher confidence and maturity	17	43
Provides a deeper appreciation for a different culture	--	65
Provides a deeper appreciation for Singapore	--	43

*Results reflect responses from K.N. Irvine's sections in physical geography

Table 3 Courses Integrating SLL Concepts and Technology

Pre-Service Teacher Courses	***Masters in Humanity Education Courses***
AAG103 *Techniques in Geography* AAG231 *Humid Tropical Environments* AAG232 *Biogeography* AAG234 *Coastal and Ocean Systems* AAG241 *Economic Geography and Globalisation* AAG242 *Urban Development and Change* AAG244 *Population and Sustainability* AAG251 *Introduction to GIS* AAG331 *Catchment Management and Conservation* AAG332 *Ecosystem Dynamics* AAG333 *Resource and Environmental Management* AAG351 *Applied GIS*	MAS 841 *Field Inquiry in Physical Geography* MAS842 *Field Inquiry in Human Geography* MAS843 *Topics in Sustainability* MAS844 *Global Cities*

Table 4 Snapshot of PUB's School Outreach Programmes To Achieve Values-based Learning Outcomes

Level	PUB's Key Programmes	Values & Attitudes	Learning Outcomes
Pre-school	● Water Education @ NVC - Raingarden Workshop ● PUB events (for example, Singapore World Water Day, ABC Waters events).	● Become curious about water through stories and inquiry learning ● Appreciates and cherish water ● Compassion for living things	● Water is critical to sustain life. ● Learns good water saving habits – for example, to brush teeth with mug and keep to short showers. ● Learn to keep our waterways clean by not littering and dirtying the environment.
Primary	● Time to Save ● Water Education @ NVC - NEWater Scientist ● PUB events	● Stay curious and cherish water ● Take ownership of our water resources - lead parents, helpers, neighbours to use water responsibly ● Pride in Singapore's water management and innovations	● Practises good water saving habits every day and especially during prolonged dry weather. ● Be aware of the 4 National Taps that gives Singapore water self-sufficiency ● Be aware of the technology behind NEWater
Secondary / Integrated Programme	● ABC Waters Learning Trails ● Water Education @ NVC - Managing Stormwater in Singapore - Fundamentals of Membrane Filtration - Youth Water Ambassador - Youth Water Ambassador ● PUB events	● Stay curious, discover and appreciate water management in Singapore through inquiry based, investigative learning ● Awareness of water issues ● A sense of social responsibility and take ownership of our waters ● Become water advocates translating learning into actions – seed volunteers	● Learns Singapore's integrated water management and flood mitigation strategies through place-based, inquiry learning, and be inspired to become a water steward

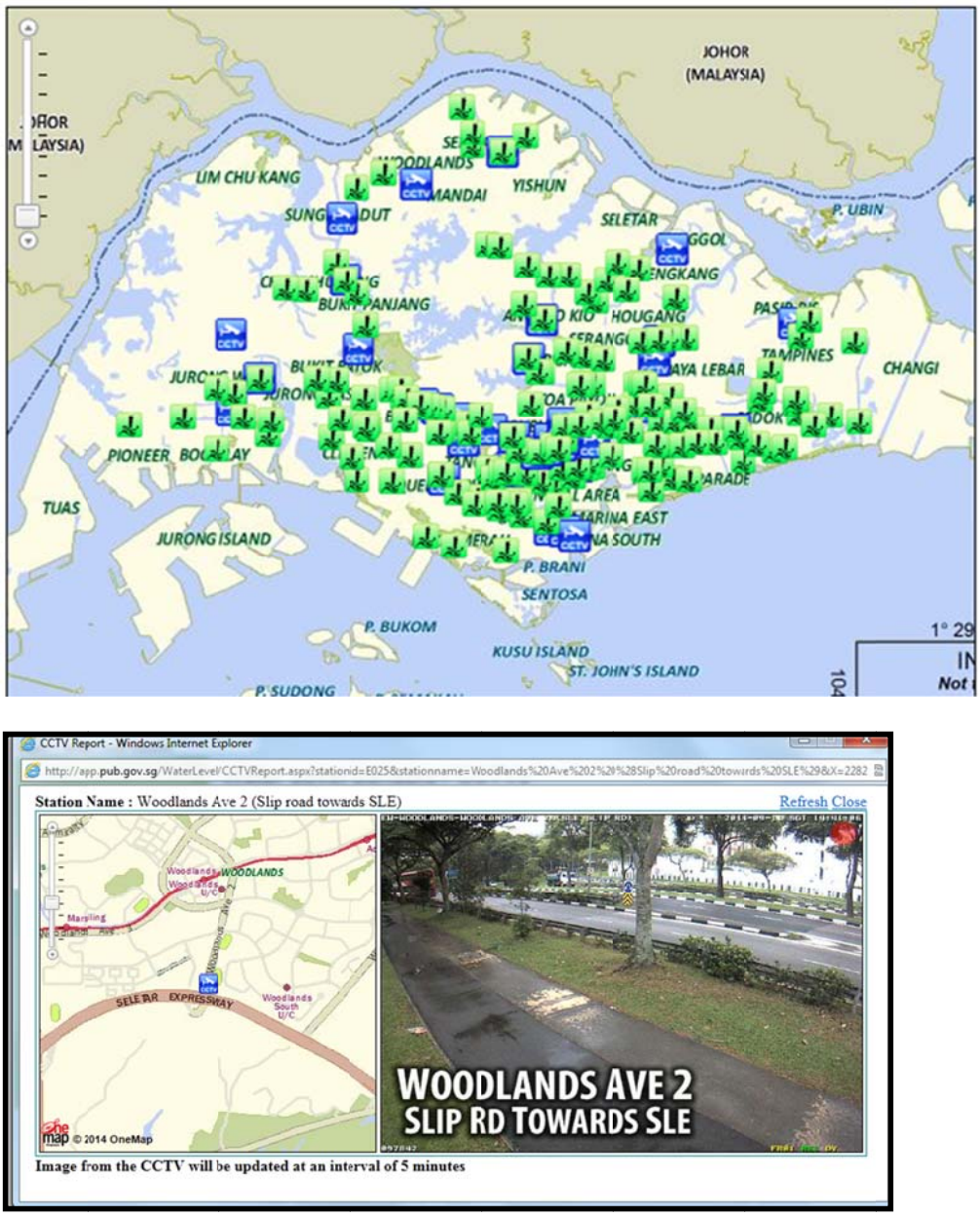

Figure 1 PUB online resources. Water level gauge locations and data (above) and CCTV camera shot from Woodlands Avenue 2 gauge station (below).

Conserve through protecting water resources

A large part of water conservation is focused on preventing pollution of the water supplies.

Protection of water resources

Everyone has a part to play in conserving water and keeping waterways clean in Singapore. As a large part of Singapore is used for water catchment, we can help by keeping drains and canals in our catchment areas clean.

In 2006, PUB launched the Active, Beautiful, Clean Waters (ABC Waters) programme to promote the enjoyment of Singapore's waters. As part of this initiative, PUB built parks near water bodies for all to enjoy and get closer to water. PUB also opened selected reservoirs and rivers for various recreational activities and water sports. Examples are paddling on a kayak or a dragonboat, wakeboarding, rowing and sailing (refer to Figure 4.65).

Figure 4.65 Kayaking in the Sengkang Floating Wetland.

PUB created an outreach programme called 'Friends of Waters'. This aims to encourage the public to care for our waterways. Schools, private and non-governmental organisations can be a 'Friend of Water' when they adopt a waterway, conduct clean-ups and help monitor its cleanliness. As volunteers, they contribute to raising awareness about protection of our water resources. Students can also go on an ABC Waters Learning Trail. This is a series of outdoor, place-based trails which encourage students to learn about Singapore's water story, heritage of water sites and unique design features that help cleanse water naturally. Students can also volunteer as a trail leader to help raise awareness about water management and appreciation for water resources (refer to Figure 4.66).

Figure 4.66 A student leading the ABC Waters Learning Trail for a group of students from another school at MacRitchie Reservoir.

Protection of waterways is only possible when the community values water. Valuing water not only helps to keep water treatment costs low, but it also keeps rivers and reservoirs clean. This creates a beautiful and clean environment.

Visit www.abcwaterslearningtrails.sg to know more about the Active, Beautiful, Clean Waters Learning Trail.

Figure 2 More detailed content on Singapore's water conservation efforts (Brown et al., 2014).

Figure 3 Measuring quality of the outflow from a biotope, Jurong Eco Garden, Singapore, using a YSI datasonde in AAG332.

Figure 4 Beach profiling at Changi Beach, Singapore, in AAG234.

Figure 5 AAG401 students studying water distribution for informal settlements in urban Hyderabad (photo credit to Dr. Diganta Das).

Figure 6 En route to sample water quality in Lake Erie aboard Buffalo State, State University of New York research vessel, AAG401 U.S. field course, 2015.

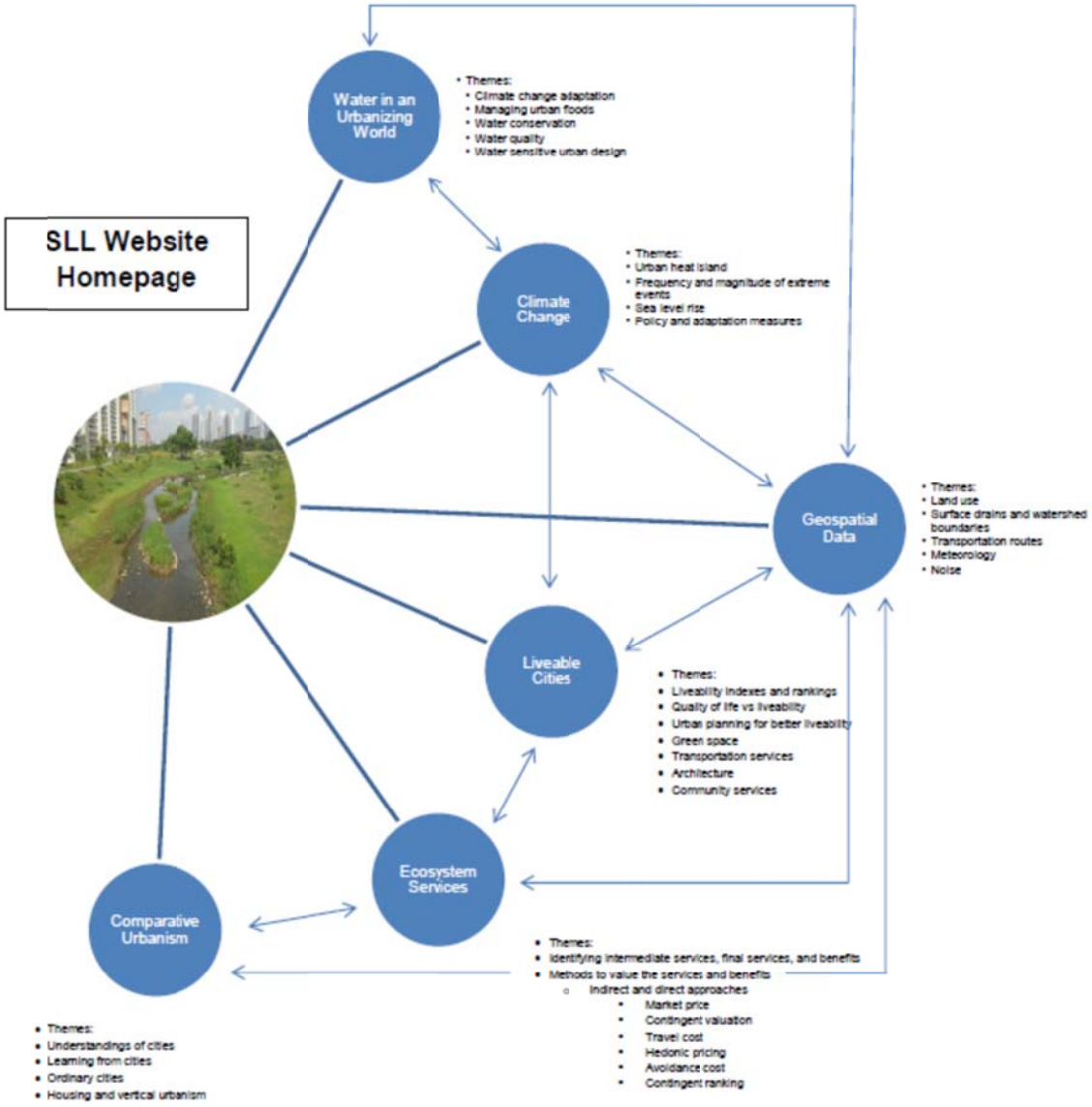

Figure 7 Summary of content under each topical theme and links between the topical theme pages and the Geospatial Data page.

Figure 8 Engaging students to be part of the "Time to Save" Water Conservation Awareness skit.

Figure 9 Young students role-playing as NEWater scientists, discovering solutions relating to NEWater, using iPod Touch gadgets.

Figure 10 Hands-on experimentation using the stormwater management model.

Figure 11 Student water ambassadors deliberating as a team before embarking on the role-playing exercise.

Figure 12 One of the FOW schools going on an ABC Waters Learning Trail @ Lower Seletar Reservoir.

Figure 13 First-of-its-kind kayaking trail created by CreativeKids and the Singapore Canoe Federation.

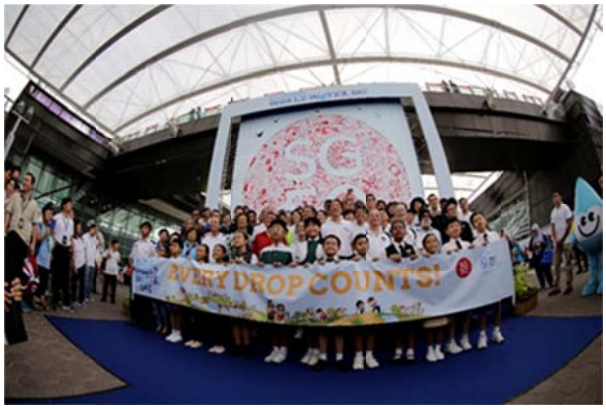

Figure 14 Community partners coming together to raise water awareness and to launch Singapore World Water Day 2015, where “Every Drop Counts”.