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Effects of water-saving education in Taiwan on public water knowledge, attitude, and behavior intention change

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Abstract

This study aims to measure the changes in the water literacy of the subjects ($N = 620$) aged over 18 before and after participating in the water-saving activities. The results showed that there is a significant improvement in the water literacy of the subjects after the water-saving activities but with a medium-small effect size; there is no significant correlation between water knowledge and water attitude before or after the activities. In addition, there is a significant difference in water literacy regarding subjects' background variables, such as age, income, and household water expenses. In other words, the attitude and behavior related to the use of water could be easily influenced by different background variables. Due to the limitation of the museum being the study field, the post-tests were given immediately following the activities, therefore the improvements of the subjects' knowledge and attitudes may not be retained over time. The findings can serve as a reference for the Water Resources Department to promote water conservation education in the future.

Keywords: Science museum; Water literacy; Water-saving education

Introduction

In the 21st century, many experts and scholars have called on the publics' attention concerning the problem of water resources, as many countries suffer from water shortage or deteriorating water quality, which further affect the nations' economic development and livelihoods (Somerville & Briscoe, 2001; Watson *et al*., 2010; Yergin, 2011). According to the World Water Resource Development Report released by the UNESCO, climate change and global warming have resulted in continuous drought in many countries. If people's water use habits are not improved, over one billion people in the world will live in drought-stricken areas by 2025 (UNESCO, 2003). To call upon its member states to pay attention to the issue of water resource development, the UN announced March 22 2020 to be World Water Day, as an indication that the global water resource crisis is imperative.

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In the past, education on water resources has been emphasized in school education; however, relevant research has shown that education on water resources in schools merely focuses on basic scientific concepts of water (Ewing & Mills, 1994). Students tend to lack a clear understanding of the cycle, source, protection, and management of water. Worse still, some teachers also lack related knowledge (Beiswenger *et al*., 1991; Ewing & Mills, 1994). To promote water knowledge, attitude, and behavior, extracurricular activities can be held to increase students' or the public's interest and enhance their awareness of water resources, aside from school education (Middlestadt *et al*., 2001; Çoban *et al*., 2011).

In Taiwan, water is mainly used for agriculture, livelihood, and industry. In recent years, the water used for livelihood and industry has increased year by year, while agricultural use has remained unchanged on average. According to the statistical data of the past three decades (1981–2010), the average annual precipitation in Taiwan is approximately 2,500 mm (Central Weather Bureau, 2011). Although this amount is 2.5 times more than the global average (730 mm), the annual precipitation per capita is merely one seventh of the global average, because the retention of rainwater is difficult due to the mountainous landforms and the steep slope of rivers in Taiwan. In face of the increasingly complicated problems of water shortage and drought, the Taiwan Water Resources Agency, which is the unit in charge of water resources, has proposed a special plan for water saving and the recycling of water resources. The plan includes enforcing the use of products with the water-saving label, holding water-saving activities, and promoting the recycling of rainwater (Water Resources Agency, 2015). The plan aims to urge the awareness of water resource protection, educate correct water knowledge, and encourage water-saving behaviors.

Related studies on water knowledge, attitude, and behavior

Water literacy should include variables such as water knowledge, attitude, and appropriate water behavior (Middlestadt *et al*., 2001; Willis *et al*., 2011). As for water knowledge, the most important thing is not only to identify water-related problems but also know how to solve them and take action (Robelia & Murphy, 2012; Dean *et al*., 2016). Beiswenger *et al*. (1991) surveyed students and teachers and found that most primary and secondary students, and even some teachers, had less water-related knowledge than expected. In particular, only about 50% of them could give a correct answer to questions involving the basic knowledge of the water cycle. Ewing & Mills (1994) investigated primary, secondary, and college students and found that about one-third of the students merely understood basic concepts, such as three basic forms of water and water as the source of life.

Knowledge has a great influence on attitude and behavior, and the influence is complicated but indirect (Robelia & Murphy, 2012). More importantly, it may influence governmental policy on water consumption. Salvaggio *et al*. (2014) conducted an investigation in the downtown area of Las Vegas and found that environmental value, knowledge, and concern are important prediction factors of water saving, and that they were interconnected. In particular, the public's understanding of water knowledge is the most powerful prediction factor that drives conservation rates to rise. Other studies have found that many factors influence water conservation behavior. These variables include information, environmental attitudes, and a range of demographic variables, such as age and education (Kollmus & Agyeman, 2002; Dolnicar *et al*., 2012).

The volume of water consumed by ordinary families and the way the water is consumed are related to the area of residence. According to Harlan *et al*. (2009), families with a larger residence tend to consume more water than those with a smaller residence. People living in larger residence should particularly use water appropriately and develop a good habit of saving water. Corral-Verdugo *et al*. (2003) investigated the residents living in two cities in northern Mexico, and found that water attitude and behavior are related to income, the size of residence, the number of family members, and garden size. Those with a higher income tend to live in a large house, and families with a large number of members tend to develop the habit of wasting water; however, if these families are equipped with water-saving equipment, their water rate may decrease significantly. Attari (2014) studied the water attitudes and behavior of 1,020 citizens and found that water attitude is correlated with water behavior, and that those with an appropriate water attitude tend to show better water behavior. In Taiwan, Cheng (2011) conducted a sampling study on 1,370 Taiwanese and surveyed their knowledge, attitude, and behavior intention of water resources. The results showed that their score on knowledge of water resources was rather low and that they were reluctant to take action, but they believed that they had developed the attitude of saving water.

According to the above literature review and the public water consumption in Taiwan, this study defined the variables in water literacy, including knowledge, attitude, and behavior intention. Water knowledge involves concepts such as water sources, the water cycle, and water recycling. The common knowledge related to water consumption in daily life was also included, such as calculating water rates, the source of tap water, water footprints, and water-saving labels. Water attitude involves the positive belief in the issue of water resources, the attitude toward environmental connections, and the attempt to know the degree of importance that Taiwanese citizens attach to water-saving equipment or methods. Water behavior intention shares a similar meaning with water attitude but focuses on the water behavior in daily life. It can be individual behavior and consists of two indexes: the supporting appropriate water behavior and changing others' water behavior. These two indexes include actual supporting water-saving actions and further influencing others' water consumption with good habits of using water. The summarized definitions of the variables are shown in Table 1.

Related studies on water-saving instruction design

Previous studies have indicated that water education can change people's water attitude and behavior, thereby enhancing their awareness of water resources (Cockerill, 2010; Mullenbach & Green, 2018). Wang (2003) suggested that activity planners focus on the aspects of water that are closely related to

Table 1. Domains, subscales, and definitions of water literacy.

Domain	Subscale	Definition
Knowledge	Basic scientific knowledge of water	Recognize the consumption unit of tap water, the power of water, and the water cycle
	Source and recycling of water	Get acquainted with the source and recycling of water
	Relationship between water use and environment	Recognize the use of water resources in society and within the family (recognize water footprint and conservation)
Attitude	Concern for the issues about water resource	Learn about the crisis of water resources and become interested in topics on water resources
	Positive attitude and values	Have the potential to solve problems caused by the reduction of water resources
Behavior intention	Appropriate and efficient use of water	Show the behavior of appropriate and efficient use of water in daily life
	Change and influence	Be able to stop others from wasting water or ask others to save water

Table 2. Characteristics of samples ($n = 620$).

Item	Category	Number of samples (n)
Gender	Male	214 (34.5%)
	Female	406 (65.6%)
Age	18–29	76 (12.3%)
	30–39	297 (47.9%
	40–49	217 (35.0%)
	Above 50	30 (4.8%)
Income[a]	20,000 or less	111 (17.9%)
	20,001–30,000	120 (19.4%)
	30,001–40,000	132 (21.3%)
	40,001–50,000	105 (16.9%)
	50,001–60,000	72 (11.6%)
	60,001 or more	80 (12.9%)
Living space[b]	60 or less	35 (5.7%)
	61–125	369 (59.5%)
	126–257	170 (27.4%)
	258 or more	46 (7.4%)
Residential water bill[c]	500 or less	199 (32.1%)
	501–1,000	263 (42.4%)
	1,001 or more	107 (17.3%)
	Do not know	51 (8.2%)
Water bill[d]	2–6	188 (30.3%)
	7–12	180 (29%)
	13–19	25 (4%)
	20–25	8 (1.3%)
	Do not know	219 (35.3%)

[a]Based on the question, What is your average monthly income? (NTD).
[b]Based on the question, What is the area of your residence? (m^2).
[c]Based on the question, What is your bimonthly water bill? (NTD).
[d]Based on the question, Do you know the price of 1,000 liters of tap water? (NTD).

our daily lives. Such an approach links water concepts to the concept networks (like the food network) of life, production, and ecology, in turn, facilitating the appropriate introduction to environment education. Covitt *et al.* (2009) mentioned that two important themes should be included in the design of water-saving education: (1) knowing the sources of water, such as recognizing the visible water resource systems and the invisible underground water systems and (2) knowing appropriate behavior of using water and how to protect water resources.

Middlestadt *et al.* (2001) designed an interactive water-saving curriculum and conducted a comparative study. There was a significant change in the water behavior and attitudes of the students who took the water-saving courses, and there was also a significant increase in their knowledge of the appropriate use of water. It demonstrated that the experiment indeed improved the students' water-saving knowledge, attitude, and behavior. Çoban *et al.* (2011) conducted a five-day survey consisting of a pre-test and a post-test among middle school students (Grades 6–8) in a school workshop and found that the workshop had a positive significant effect on the development of the students' behavior toward water usage and in improving their attitudes. Grieser *et al.* (1997) designed a water-saving curriculum using GreenCOM. After one semester of the curriculum, the students' scores in the pre-test and the post-test were used to assess the effectiveness of the curriculum. In addition, the students were also taught how to read a water bill so that they could pay attention to the water consumption of their families, and check if they had reduced their water consumption at home.

Instead of adopting formal education at school, Harness & Drossman (2011) designed a learning activity involving the making of short videos and asked high school students to discuss issues on grey water recycling and water conservation. The findings of the study showed that the students' concern about water resources was influenced by their families, schools, or the media. That study suggested that schools should provide more activities or courses about water saving. The students who participated in the video-making program also indicated that they had become more concerned about water resources and would take action to set a model for their friends and family members.

Water education can be offered through formal education at school or in an informal education environment (Liou *et al*., 2014). In most cases, informal water education is provided by NGOs or institutions of social education, such as zoos, museums, and natural interpretation centers (Simmons *et al*., 2004; CEGN, 2006). Science museums can make use of their unique educational features to emphasize practice-based/interactive learning. They can also organize participatory experience-based educational activities under the operating principle of sustainability to encourage citizens to join in the activities (Alexander & Weinland, 1985; Falk *et al*., 1986). By taking the Utilizing of Water Resources Exhibition at the National Science and Technology Museum (NSTM) as the research field, Chen (2012) explored whether the interactive exhibitions met the NSTM's objective of popularizing the education on the conservation of water resources. The findings suggested that the exhibition played a role in water education and aroused the interviewees' awareness of saving water resources. Liou *et al*. (2014) held interesting practice-based water-saving activities in NSTM and invited citizens to the interactive experience. Through the pre-test and the post-test questionnaire surveys, they explored the change of the public awareness in saving water after the activities. The activities were effective in arousing public understanding and interest in issues about water resources. The water-saving activities in the museum could also be held in the form of a competition, where family members acquire scientific concepts of saving water through cooperative learning. Through a qualitative interview and a conceptual graph, Chang *et al.* (2010) studied the students who took part in the water-saving creativity competition and found that the participants indeed had a deeper understanding of the scientific concepts of water saving after the competition.

Research questions

In this study, features of the informal educational environment of the NSTM were considered to elaborate on the public understanding of water knowledge, attitude, and behavior intention. To evaluate the effectiveness of water-saving activities, the pre-test and post-test were adopted to assess the learning achievements of the public. This study addressed the following research questions:

R1: Do water-saving activities improve public water knowledge, water attitude, and water behavior intention after completing water-saving activities?

R2: Do individuals discuss the correlation among and the change of water knowledge, water attitude, and water behavior intention?

R3: Is there any change in the water knowledge, water attitude, and water behavior intention of individuals with different background variables after completing water-saving activities?

Methods

Procedure and participants

This study was conducted in NSTM, which was the first museum of applied science in Taiwan, as well as the first national institute of public education in southern Taiwan. The subjects of this study were Taiwanese citizens who participated in the water-saving activities held by NSTM. The subjects filled out the pre-test questionnaire upon arrival at the museum and then began the water-saving activities. Through instruction and hands-on practice, they acquired the knowledge of water saving so that they would have a stronger awareness of saving water. After the activities, they filled out the post-test questionnaire. The difference in public water knowledge, attitude, and behavior before and after the water-saving activities was measured.

Water-saving activities

The water-saving activities were based on the principle of living technology education in Taiwan and were designed by professionals at the science museum. Most of the activities involved large teaching aids and were designed to increase the subjects' interest in water-related issues through hands-on activities. Before the activities, the researchers of the museum offered training to the instructors of the teaching aids to ensure the accuracy of the instruction. The water-saving education activities of this study involved 10 interactive teaching aids. The experience time for the operation of each teaching aid was limited to not more than five minutes. It took about 50 minutes for each subject to go through the water-saving activities. There are three key messages in the water-saving activities so that the subjects could acquire correct water knowledge and change their water attitudes and behavior. The key messages of each teaching aid are as follows:

- Where does water come from? This message tells the subjects the sources of tap water in Taiwan (including reservoirs, underground water, and rivers). Most importantly, the activities tell the subjects that the tap water at home needs to be filtered and disinfected before it is delivered to households. This message also shows the subjects that both surface water and underground water are precious water resources that should be used cautiously and should not be wasted.
- How to save water? This message mainly shows how to save water in daily life, such as equipping taps or toilets with water-saving equipment. The activities also aim to urge the subjects to check for leakage of water equipment on a regular basis so as to prevent the wasting of water resources.
- How to recycle grey water? This message shows that grey water can be recycled. For instance, rainwater can be recycled to clean floors, flush toilets, and water flowers. This message is especially useful for people in Taiwan, where most houses are equipped with RO water-filtering devices that generate much grey water. The activities aim to encourage subjects to recycle grey water and save water resources.

The survey instruments

The questionnaire of this study was based on the Water Literacy Scale (see Tables A1 and A2 in Appendix 1, in the Supplementary Material available with the online version of this paper) by Wang *et al.* (2016), and a trial survey of the questionnaire was conducted when the water-saving activities were held in NSTM. The majority of the questionnaire items were related to the teaching aids, especially in water knowledge. For example, the water-saving taps demonstrated the level of water saving at different facilities; the teaching aids for recycling of rainwater demonstrated that recycled rainwater can be used for mopping the floor or flushing the toilet.

To facilitate the sampling, adults aged over 18, who entered NSTM, were chosen as the subjects. A total of 100 copies of the questionnaire were distributed for the pilot test. Project analysis and factor analysis were conducted for the pilot test. The survey instrument consisted of three parts. Part 1 involves personal information, including gender, age, income, area of residence, and water expense at home. Part 2 covers water knowledge questions presented in the form of multiple choice answers. These questions are divided into three sub-scales, namely basic scientific knowledge of water (three items), source and recycling of water (six items), and correlation between use of water and environment (eight items). According to the discrimination analysis, the difficulty ranged from 0.40 to 0.85, and the relevance of Part 2 was significant, suggesting that the difficulty of the items is moderate and highly discriminant. Part 3 involves water attitude and water behavior intention items, and is scored using a 7-point Likert scale. Each water attitude item is divided into two sub-scales: concern for water resource issues (three items) and attitude and values (six items). Each water behavior item is divided into two sub-scales: appropriate and efficient use of water (five items) and change and influence (five items). According to the item analysis and the factor analysis of the above variables of water attitude and behavior, the factor loadings range from 0.48 to 0.85. The Cronbach's α of the above variables ranges from 0.71 to 0.93, meeting the criterion suggested by Nunnally & Bernstein (1994) that reliability should be higher than 0.70. The reliability of the scale is therefore high and acceptable.

Data collection

In this study, 690 copies of the questionnaire were issued and 662 were retrieved. After eliminating the invalid samples, there were 620 valid samples, with a valid return rate of 92.5%. In terms of gender, there are 406 females (65.5%), while males account for 34.5%. As for age, 297 respondents age from 30 to 39 years old, followed by 40 to 49 (217 respondents). In terms of monthly income, the average monthly income of 30,000–40,000 NTD is the highest (21.3%), followed by 20,000–30,000 (120, 19.4%). This suggests that visitors have a stable income and visit the museum with family members. As for the bimonthly water bill, 501–1,000 NTD (263, 42.4%) ranks the highest, which is slightly higher than the average of 462 NTD in 2016 (Taiwan Water Corp., 2017). For the question on the rate for 1,000 liters of tap water, 34.9% of the subjects failed to give an answer, while only 29% gave a correct answer (about 7–12 NTD for 1,000 liters). This indicates that the respondents should know more about their water expenses and that the water rate may be too low to catch the attention of the subjects.

Findings and discussion

Research question 1: Did the water-saving activities improve public water knowledge, water attitude, and water behavior intention after completing the water-saving activities?

This study conducted a paired-sample *t*-test of the pre- and post-test on three factors (basic scientific knowledge of water, source and recycling of water, and the relationship between use of water and environment) before the activities, to see if there was any difference in learning effectiveness among the objectives. The results of the analysis of relevant averages are shown in Table 3. With knowledge

Table 3. Paired-samples *t*-test results of water knowledge scores ($n = 620$).

Knowledge	Pre-test		Post-test			
	M	*SD*	*M*	*SD*	*t*-Test	Effect size *d*
Basic scientific knowledge of water	1.74	0.87	2.25	0.75	12.772***	0.63
Source and recycling of water	3.11	1.21	3.74	1.21	11.734***	0.52
Relationship between water use and environment	6.06	1.37	6.88	1.24	12.086***	0.63

***$p < 0.001$.

of water, there is a significant change to all the factors of public water knowledge after the activities, with a medium effect size. The results demonstrate that the water-saving activities have positive effects on the public knowledge of water resources.

Table 4 shows that the relationship between the use of water and environment has the highest answer accuracy (76% before the activities and 86% after the activities). This suggests that the subjects have a stronger awareness of the importance of appropriate water use and the relationship between water protection and environment. As far as source and efficient use of water are concerned, the answer accuracies before and after the activities are the lowest (52% before the activities and 62% after the activities). This means that the subjects should improve their understanding of the sources of water and water recycling. Moreover, there is a limited increase in their answer accuracy after the activities. This is consistent with Liou *et al*. (2014), who found that policies on water recycling have not been widely implemented across Taiwan, and that relevant governmental departments should enhance public awareness on the importance of grey water recycling.

To analyze the change in public water attitude, this study conducted a paired-sample *t*-test of the pre- and post-test on two factors (concern for water resource issues and attitude and values) before the activities. The results are shown in Table 5. As for water attitude, there is a significant change in all the factors of public water attitude after the activities but with a small effect size ($d = 0.18$ and $0.14 < 0.2$), indicating that the water-saving activities could influence public attitude toward water resources. Although the *t*-test showed significance, the mean of the post-test value did not increase significantly, and the effect size was small, hence, the actual difference was not big. To further compare the factors, an analysis of covariance between factors was conducted. The results of the post hoc comparison of the means of the factors before and after the activities are shown in Table 6. The mean of attitude and values is higher

Table 4. Answer accuracy of water knowledge after water-saving activities and analysis of covariance between factors.

Knowledge	*M*	No. of items	Answer accuracy	*F*	Post hoc result
Pre-test					
1. Basic scientific knowledge of water	1.74	3	58%	256.184***	3 > 1 > 2
2. Source and recycling of water	3.11	6	52%		
3. Relationship between water use and environment	6.06	8	76%		
Post-test					
1. Basic scientific knowledge of water	2.25	3	75%	283.948***	3 > 1 > 2
2. Source and recycling of water	3.74	6	62%		
3. Relationship between water use and environment	6.88	8	86%		

***$p < 0.001$.

Table 5. Water attitude using paired-samples *t*-test ($n = 620$).

Attitude	Pre-test *M*	Pre-test *SD*	Post-test *M*	Post-test *SD*	*t*-Test	Effect size *d*
Concern for the issues about water resource	14.36	3.25	14.91	2.86	4.571***	0.18
Positive attitude and values	39.24	4.59	39.87	4.12	4.110***	0.14

***$p < 0.001$.

Table 6. Water attitude analysis of covariance between factors after water-saving activities.

Attitude	*M*	No. of items	*M*	*F*	Post hoc result
Pre-test					
1. Concern for the issues about water resource	14.36	3	4.79	1615.971***	2 > 1
2. Positive attitude and values	39.24	6	6.54		
Post-test					
1. Concern for the issues about water resource	14.92	3	4.97	1844.224**	2 > 1
2. Positive attitude and values	39.87	6	6.65		

**$p < 0.01$; ***$p < 0.001$.

than that of concern for water resource issues. This is consistent with Wang *et al.* (2016), who found that the subjects have developed a positive attitude toward the protection of water resources.

This study conducted a paired-sample *t*-test of the pre- and post-test on two factors (appropriate and efficient use of water and influence and change) before the activities. The results are shown in Table 7. As for water attitude, there is a significant change (increase) to all the factors of public water behavior intention after the activities, with a medium-small effect size ($d = 0.21$ and $0.27 < 0.3$), suggesting that water-saving activities could influence public water behavior intention. However, due to the small size of statistical effect, the actual difference should be evaluated conservatively. To further compare the factors, an analysis of covariance between factors was conducted. The results of the post hoc comparison of the means of the factors before and after the activities are shown in Table 8. The mean of appropriate and efficient use of water is higher than that of influence and change. This is consistent with Wang *et al.* (2016), who found that most individuals have the awareness of appropriate and efficient use of water, but that their intention of influencing or changing others' water use is not strong. The result is consistent with Cheng (2011), who found that individuals do not actively protect water resources and seldom take actions to change water behavior.

Research question 2: Did the participants discuss the correlation among and the change in water knowledge, water attitude and water behavior intention?

Table 7. Water behavior intention using paired-samples *t*-test ($n = 620$).

Behavior intention	Pre-test *M*	Pre-test *SD*	Post-test *M*	Post-test *SD*	*t*-Test	Effect size *d*
Appropriate and efficient use of water	32.05	4.39	32.91	3.88	5.765***	0.21
Change and influence	30.80	5.33	32.16	4.57	7.279***	0.27

***$p < 0.001$.

Table 8. Water behavior intention analysis of covariance between factors before and after water-saving activities.

Behavior intention	*M*	No. of items	*M*	*F*	Post hoc result
Pre-test					
1. Appropriate and efficient use of water	32.05	5	6.41	82.41***	1 > 2
2. Change and influence	30.80	5	6.16		
Post-test					
1. Appropriate and efficient use of water	32.91	5	6.58	46.962***	1 > 2
2. Change and influence	32.16	5	6.43		

***$p < 0.001$.

Table 9 presents the correlation coefficients between the knowledge, attitude, and behavioral domains. This study explored the correlation among water knowledge, water attitude, and water behavior. There is a strongly significant correlation ($r = 0.725$) between water attitude and water behavior intention before and after the activities. It is obvious that water attitude interacts with water behavior. Those who are more concerned about water resource issues show better water behavior in daily life. However, after the activities, there is a slightly significant correlation ($r = 0.105$) between water knowledge and water behavior intention. This result indicates that the increase in public water knowledge after the activities has an indirect effect on the subjects' water behavior. There is no significant correlation between water knowledge and water attitude before or after the activities. In other words, the subjects' awareness of their water-saving attitude is irrelevant to their participation in the activities.

Research question 3: Was there any change in the water knowledge, water attitude, and water behavior intention of subjects with different background variables after completing the water-saving activities?

1. Analysis of the effects of gender and age on water literacy

   According to Tables 10 and 11, there is no significant difference in water knowledge, water attitude, or water behavior intention among subjects of different ages after the activities. In terms of age, there is a significant difference in water behavior intention after the activities ($F = 4.803$; $p < 0.01$). The post

Table 9. Pearson's coefficients between water knowledge, attitude, and behavior intention.

Inter-correlation	Pre-test	Pro-test
Knowledge vs. Attitude	0.049	0.023
Knowledge vs. Behavior intention	0.078	0.105**
Attitude vs. Behavior intention	0.725***	0.787***

**$p < 0.01$; ***$p < 0.001$.

Table 10. Analysis of the relationship between gender and variables.

	Gender	*N*	*M*	*SD*	*t*-Test	*p*
Knowledge	Male	214	12.97	2.30	0.712	0.477
	Female	406	12.83	2.40		
Attitude	Male	214	54.91	5.35	0.370	0.711
	Female	406	54.73	5.96		
Behavior intention	Male	214	64.57	7.37	− 1.116	0.265
	Female	406	65.33	8.33		

Table 11. Analysis of the relationship between age and variables.

	Age (years)	*N*	*M*	*SD*	*F*	*p*	Post hoc result
Knowledge	1. 18–29	76	13.28	2.225	2.015	0.111	
	2. 30–39	297	12.87	2.263			
	3. 40–49	217	12.86	2.433			
	4. Above 50	30	12.03	2.965			
Attitude	1. 18–29	76	53.83	6.436	1.184	0.315	
	2. 30–39	297	54.69	6.083			
	3. 40–49	217	55.23	4.895			
	4. Above 50	30	55.03	6.139			
Behavior intention	1. 18–29	76	62.25	10.707	4.803**	0.003	2 > 1
	2. 30–39	297	65.14	7.911			3 > 1
	3. 40–49	217	66.14	6.538			
	4. Above 50	30	63.73	9.310			

$^{**}p < 0.01$.

hoc comparison found that the scores of water behavior for subjects aged 30–39 and 40–49 are higher than the scores of those aged 18–29. This indicates that the activities could lead to an increase in the appropriate water behavior of middle-aged and senior citizens. However, the age factor did not show any influence on the respondents' water knowledge and attitude after participating in the activities.

2. Analysis of the relationship between area of residence and water literacy

   As shown in Table 12, 369 subjects live in homes with a floor area ranging from 61 m^2 to 125 m^2, which are small- and medium-sized. The study results showed that the residence size does not have an effect on water knowledge, attitude, and behavior. However, the scores for subjects with area of 61 m^2 to 125 m^2 are higher in terms of the three variables. This demonstrates that those living in a smaller residence would show better water knowledge, attitude, and behavior and would be highly cautious after the activities.

3. Analysis of the relationship between average monthly income and water literacy

   According to Table 13, 132 subjects have an average monthly income of 30,000–40,000 NTD (132, 21%), followed by 20,000–30,000 NTD (120, 19%). These two groups are considered

Table 12. Analysis of area of residence and variables.

	Living space (m^2)	*N*	*M*	*SD*	*F*	*p*
Knowledge	Below 60	35	12.91	2.381	0.901	0.441
	61–125	369	12.97	2.377		
	126–257	170	12.79	2.305		
	258 or above	46	12.39	2.445		
Attitude	Below 60	35	54.69	5.666	0.026	0.980
	61–125	369	54.83	6.030		
	126–257	170	54.81	5.385		
	258 or above	46	54.46	4.875		
Behavior intention	Below 60	35	64.91	7.644	1.105	0.346
	61–125	369	65.52	7.872		
	126–257	170	64.47	8.176		
	258 or above	46	63.78	8.794		

Table 13. Analysis of the relationship between average monthly income and variables.

	Income (NTD)	*N*	*M*	*SD*	*F*	*p*	Partial η^2	Post hoc result
Knowledge	1. 20,000 and under	111	13.14	2.350	4.299**	0.001	0.034	1 > 2
	2. 20,001–30,000	120	12.03	2.477				4 > 2
	3. 30,001–40,000	132	12.87	2.342				5 > 2
	4. 40,001–50,000	105	13.05	2.073				6 > 2
	5. 50,001–60,000	72	13.10	2.240				
	6. 60,001 and above	80	13.34	2.460				
Attitude	1. 20,000 and under	111	54.61	6.023	.132	0.985		
	2. 20,001–30,000	120	54.89	6.470				
	3. 30,001–40,000	132	54.58	6.173				
	4. 40,001–50,000	105	55.11	5.912				
	5. 50,001–60,000	72	54.76	4.040				
	6. 60,001 and above	80	54.83	4.594				
Behavior intention	1. 20,000 and under	111	63.18	9.618	1.644	0.141		
	2. 20,001–30,000	120	65.73	8.596				
	3. 30,001–40,000	132	65.64	7.826				
	4. 40,001–50,000	105	65.48	7.478				
	5. 50,001–60,000	72	64.75	5.816				
	6. 60,001 and above	80	65.51	7.146				

Note: Partial eta squared indicates a very small effect size.
**$p < 0.01$.

high- and medium-income groups. There is no significant difference in water attitude or water behavior among subjects with different average monthly incomes. However, there were significant differences after participating in the activities, among which the group with monthly income of 20,000–30,000 NTD performed the worst, indicating that people in this income group have lower willingness to learn about relevant water knowledge.

4. Analysis of the relationship between water rate and water literacy

   According to Table 14, 263 subjects have bimonthly water expense of 501–1,000 NTD (263, 42%), followed by less than 500 NTD (199, 32%), which is slightly higher than the national average of 231 NTD per month in the past five years (Taiwan Water Corp., 2017). There is no significant difference in the correlation between water expense and water knowledge or water attitude. However, in terms of water behavior, the scores of the subjects who realized that their household water expense is higher than the scores of those who do not. This result indicates that the subjects who pay attention to the water expense are more cautious about water use.

Conclusion

Due to the impact of extreme climates, the water shortage crisis has worsened in recent years. In Taiwan, the awareness of water conservation has been raised due to publicity by schools, governmental institutions, and the media. In terms of water knowledge, the subjects presented the lowest score in water recycling, and only 50% of the subjects gave a correct answer to questions about the source of water and

Table 14. Analysis of the relationship between the bimonthly water expenses and variables.

	Water bill (NTD)	*N*	*M*	*SD*	*F*	*p*	Partial η^2	Post hoc result
Knowledge	1. Below 500	199	13.07	2.366	1.291	0.276		
	2. 501–1,000	263	12.76	2.480				
	3. 1,001 or above	107	12.64	2.220				
	4. Unsure	51	13.20	1.950				
Attitude	1. Below 500	199	55.40	4.117	1.470	0.222		
	2. 501–1,000	263	54.60	6.552				
	3. 1,001 or more	107	54.64	5.157				
	4. Unsure	51	53.71	7.590				
Behavior intention	1. Below 500	199	66.40	5.951	5.720**	0.001	0.027	1 > 4
	2. 501–1,000	263	64.62	8.726				2 > 4
	3. 1,001 or more	107	65.40	7.341				3 > 4
	4. Unsure	51	61.47	10.979				

Note: Partial eta squared indicates a very small effect size.
**$p < 0.01$.

the recycling of grey water or rainwater. This suggests that the subjects have inadequate knowledge of water recycling. However, for the questions about the relationship between the use of water and environment, they presented the highest answer accuracy (80%), meaning that the subjects realized that water is closely related to the environment. For instance, they all knew that the manufacturing process generates a water footprint and that water pollution has an impact on the environment. Additionally, some subjects had little idea about water fee rates. Of the subjects, 70% did not know the fee for 1 m^3 of water. According to the survey on the capitals of major countries around the world conducted by IWA (International Water Association, 2017), the average annual per capita water consumption of Taipei (the capital of Taiwan) ranks fourth globally. However, 100 m^3 of water costs only about 73 USD in Taipei, which is relatively lower than the price in other developed countries. For example, it costs 212 USD in Tokyo, 463 USD in New York, and 385 USD in London. The water rate is so low in Taiwan that people pay little attention to it, and this may cause the waste of water resources.

There is a significant improvement in water attitude after the activities. However, the effect size is small, indicating that the activities have a limited impact on the subjects' performance in attitude. The subjects believed that 'government agencies or schools should promote more water-saving equipment and water-saving methods' and even need to 'promote the labeling of water footprint on products'. These results showed that to protect water resources, the general public not only need to pay special attention to and learn about water resources issues, but also should have higher expectation that the government institutions could attach importance and take active measures.

As far as the water behavior intention is concerned, the research results indicated that appropriate and efficient use of water scored significantly higher than change and influence. The appropriate and efficient use of water include behaviors such as taking a shower to save water, purchasing products with the water-saving label, and immediately repairing water leakage of toilets or faucets. This result indicates that the subjects have the awareness of water-saving. The change and influence consist of behavior such as reminding people to use mugs or tumblers, encouraging family members or friends to recycle grey water, and reporting conduct that causes water pollution to relevant governmental departments; however, the subjects lacked a dynamic attitude. This indicates that the subjects' influence on individuals around them is insufficient.

The background variables included gender, educational background, personal income, size of residence, and water bill. The analysis of the performance after the activities indicated that there is a significant difference in age, income, and household water rate. This result is consistent with Corral-Verdugo *et al*. (2003) and Cheng (2011), who found that water attitude and behavior are easily influenced by different background variables.

Limitations and suggestions for future research

The activities in this study effectively enhanced the subjects' general understanding of water use, but their understanding of water recycling needed to be strengthened. In future activities held by the NSTM, there are several parts needed to be improved, such as design relevant activities to introduce the methods and benefits of recycling water, using simple teaching aids to attract more visitors and involve them in the activities.

There are some limitations of this study. First, due to the limited visit time of the subjects in the museum, the post-tests were given almost immediately following the activities. The statistical data showed that the subjects had made improvements on correcting water knowledge, water attitude, and behavioral intentions, but the improvements may not persist over time. It is suggested that future research can add interviews or long-term follow-up to explore the actual results and influencing factors of people's participation in activities.

The NSTM is situated in Kaohsiung, and most of the subjects live in southern Taiwan. Due to this geographic limitation, the results of the survey may not generalize to other areas of Taiwan. It is suggested that future studies can conduct surveys in other regions of Taiwan, so as to make the research results more representative. In the future water education for the public, the topics should be determined during the design stage of activities, to promote water knowledge and improve public water attitude and behavior.

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References

Alexander, M. & Weinland, T. P. (1985). Museums and schools – the learning imperative. *Social Education 49*(7), 563–566.

Attari, S. Z. (2014). Perceptions of water use. *Proceedings of the National Academy of Sciences 111*, 5129–5134.

Beiswenger, R., Sturges, E. L. & Jones, R. (1991). Water education in Wyoming: assessing educators' knowledge of water topics and their use in the elementary curriculum. *The Journal of Environmental Education 23*(1), 24–29.

CEGN (Canadian Environmental Grantmakers' Network) (2006). Environmental education in Canada. *CEGN Briefing Papers 3*, 17.

Chang, M.-C., Chu, Y.-M., Kuo, F.-C. & Chen, L.-C. (2010). The analysis of technology concept changes for participants in water-saving innovation contest. *Journal of Industrial Technology Education 3*, 61–67. doi: 10.6306/JITE.2010.3.8.

Chen, C.-Y. (2012). The influence of the utilization of water resources exhibition hall in the national science and technology museum on middle-class elementary students' water saving behavior. *Technology Museum Review 16*(1), 145–170.

Cheng, Y.-C. (2011). *Survey and Analysis of the Understanding, Attitude, and Behavior in Water Resources Related Infrastructure Issue of the General Public in Taiwan*. Unpublished Master's thesis, National Taiwan Normal University, Taipei.

Çoban, G. Ü., Akpınar, E., Küçükcankurtaran, E., Yıldız, E. & Ergin, Ö. (2011). Elementary school students' water awareness. *International Research in Geographical and Environmental Education 20*(1), 65–83. doi:10.1080/10382046.2011.540103.
Cockerill, K. (2010). Communicating how water works: results from a community water education program. *The Journal of Environmental Education 41*(3), 151–164.
Corral-Verdugo, V., Bechtel, R. B. & Fraijo-Sing, B. (2003). Environmental beliefs and water conservation: an empirical study. *Journal of Environmental Psychology 23*(3), 247–257.
Covitt, B. A., Gunckel, K. L. & Anderson, C. W. (2009). Students' developing understanding of water in environmental systems. *The Journal of Environmental Education 40*(3), 37–51.
CWB (Central Weather Bureau) (2011). *Climate statistics*. Available at: http://www.cwb.gov.tw/V7/climate/monthlyMean/Taiwan_precp.htm (accessed March 10 2017).
Dean, A. J., Fielding, K. S. & Newton, F. J. (2016). Community knowledge about water: who has better knowledge and is this associated with water-related behaviors and support for water-related policies? *PLoS ONE 11*, 7. doi: 10.1371/journal.pone.0159063.
Dolnicar, S., Hurlimann, A. & Grun, B. (2012). Water conservation behavior in Australia. *Journal of Environmental Management 105*, 44–52. doi:10.1016/j.jenvman.2012.03.042.
Ewing, M. S. & Mills, T. J. (1994). Water literacy in college freshmen: could a cognitive imagery strategy improve understanding? *The Journal of Environmental Education 25*(4), 36–40.
Falk, J. H., Koran, J. J. & Dierking, L. D. (1986). The things of science: assessing the learning potential of science museums. *Science Education 70*, 503–508.
Grieser, M., Rawlins, B. & Tbbbaishat, K. (1997). Water conservation in Jordan. *Green Teacher 50*, 25–80.
Harlan, S., Yabiku, S., Larsen, L. & Brazel, A. (2009). Household water consumption in an arid city: affluence, affordance, and attitudes. *Society and Natural Resources 22*, 691–709.
Harness, H. & Drossman, H. (2011). The environmental education through filmmaking project. *Environmental Education Research 17*(6), 829–849.
IWA (International Water Association) (2017). *Total charges for 198 cities in 2017 for a consumption of 100 M³*. Available at: http://waterstatistics.iwa-network.org/graph/12 (accessed June 8 2019).
Kollmus, A. & Agyeman, J. (2002). Mind the gap: why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research 8*(3), 239–260.
Liou, J.-R., Chen, Y.-C. & Wang, Y.-H. (2014). A study on the effects of the science museum's water-saving activities. *Technology Museum Review 18*(4), 87–112.
Middlestadt, S., Grieser, M., Hernandez, O., Tubaishat, K., Sanchack, J., Southwell, B. & Schwartz, R. (2001). Turning minds on and faucets off: water conservation education in Jordan. *The Journal of Environmental Education 32*(2), 37–45.
Mullenbach, L. E. & Green, G. T. (2018). Can environmental education increase student-athletes' environmental behaviors? *Environmental Education Research 24*(3), 427–444. doi:10.1080/13504622.2016.1241218.
Nunnally, J. C. & Bernstein, I. H. (1994). *Psychometric Theory*, 3rd edn. McGraw-Hill, New York, NY.
Robelia, B. & Murphy, T. (2012). What do people know about key environmental issues? A review of environmental knowledge surveys. *Environmental Education Research 18*(3), 299–321.
Salvaggio, M., Futrell, R., Batson, C. D. & Brents, B. G. (2014). Water scarcity in the desert metropolis: how environmental values, knowledge and concern affect Las Vegas residents' support for water conservation policy. *Journal of Environmental Planning and Management 57*(4), 588–611. doi: 10.1080/09640568.2012.75680610.1080/09640568.2012.756806.
Simmons, B., McCrea, E., Shotkin, A., Burnett, D., McGlauflin, K., Osorio, R., Prussia, C., Spencer, A. & Weiser, B. (2004). *Nonformal Environmental Education Program: Guidelines for Excellence*. National of America, Washington, DC. Available at: http://naaee.org/npeee/nonformal/nonformalguidelines.pdf (accessed June 23 2017)
Somerville, C. & Briscoe, J. (2001). Genetic engineering and water. *Science 292*, 2217.
TWC (Taiwan Water Corporation) (2017). *Water Charges Per Household of livelihood Per Month & Rate of Annual Water Charges*. Available at: https://www.water.gov.tw/public/Data/20170821101008088.xls (accessed May 16 2017).
UNESCO (United Nations Education, Scientific Cultural Organization) (2003). *World Water Assessment Programme. The United Nations World Water Development Report: Water for People, Water for Life*. UNESCO, Paris, and Earthscan, London. Available at: https://sustainabledevelopment.un.org/content/documents/WWDR_english_129556e.pdf (accessed March 23 2017).

Wang, C. (2003). Ecological foundation and concepts for environmental education. *Journal of Environmental Education 2*, 9–46.

Wang, Y.-H., Chang, M.-C. & Liou, J.-R. (2016). A study of developing a survey for assessing public water literacy. *Journal of Environmental Education Research 11*(2), 41–77. doi:10.6555/JEER.12.1.041.

Watson, R., Boudreau, M. C. & Chen, A. J. (2010). Information systems and environmentally sustainable development: energy informatics and new directions for the IS community. *Management Information Systems Quarterly 34*(1), 23–38.

Willis, R. M., Stewart, R. A., Panuwatwanich, K., Williams, P. R. & Hollingsworth, A. L. (2011). Quantifying the influence of environmental and water conservation attitudes on household end use water consumption. *Journal of Environmental Management 92*, 1996–2009.

WRA (Water Resources Agency) (2015). Policy for *2015*. Available at: file:///C:/Documents%20and%20Settings/0175/My%20Documents/Downloads/08.%E7%B6%93%E6%BF%9F%E9%83%A8.pdf (accessed May 10, 2017).

Yergin, D. (2011). *The Quest: Energy, Security, and the Remaking of the Modern World*. Penguin Press, New York, NY.

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