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Using discovery maps as a free-choice learning process can enhance the effectiveness of environmental education in a botanical garden

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Botanical gardens (BGs) are important agencies that enhance human knowledge and attitude towards flora conservation. By following free-choice learning model, we developed a 'Discovery map' and distributed the map to visitors at the Xishuangbanna Tropical Botanical Garden in Yunnan, China. Visitors, who did and did not receive discovery maps, were evaluated through a questionnaire and behavioural observations. The map-users scored significantly higher on knowledge than non-map-users. Map-users tended to spend more time and pay more attention to plants during tours than the non-map-users. The study provides evidence to indicate using discovery maps as a free-choice learning process can improve visitors' engagement during the visit and may enhance the effectiveness of environmental education in botanical garden.

Keywords: botanical garden; environmental education; free-choice learning; questionnaire

Introduction

Education is a key function of modern botanical gardens (BGs) (Wyse Jackson and Sutherland 2000). BGs are very attractive visitor destinations worldwide, with over 200 million people visiting BGs each year (Willison 2006). The accessibility of BGs to the general public allows these gardens to play a role in the enhancement of people's knowledge about plants, awareness of biodiversity as well as supporting research and conservation efforts (Miller et al. 2004; Dosmann 2007). By taking advantage of their living collections, illustrating plant diversity and beauty, and the expertise of staff members, many BGs can provide updated information regarding conservation. A questionnaire conducted by the Botanical Garden Conservation International (BGCI) indicated 107 out of 118 BGs include education in their mission or vision and 79 out of 117 BGs allocate specific budget for education work (Kneebone 2007). The BG community has realized that public education is imperative for biodiversity conservation, and the importance of public education has also been stated and emphasized in several international agendas, such as the 'Convention on Biological Diversity' (UNEP 1992), and the 'Global Strategy on Plant Conservation' (CBD 2002).

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Tremendous efforts have been made by world-leading BGs, as well as by some established BGs in developing countries, to promote education and public engagement in environmental conservation (Willison 2006; Kneebone 2007; Kneebone and Willison 2007). The Missouri Botanical Garden, one of leading BGs in USA, provides a regular educational programme that reaches 108,000 children and 2700 teachers annually (Miller et al. 2004). A new initiative launched by another American BG, Fairchild Tropical Botanic Garden, provides an annual standards-based, environmental education outreach that engaged more than 120,000 students and teachers in 2010 and 2011 (FTBG 2012). Xishuangbanna Tropical Botanical Garden (XTBG), a major BG in China (Huang et al. 2002), has set up a 2200 m^2 visitor education centre to present information about local natural history. The centre attracts over 50% of the BG's annual 500,000 visitors and shows promise for fulfilling the educational function of the BG (He and Chen 2012).

Many educational programmes conducted in BGs are on the ground practices that often lack sufficient evaluation in terms of their effectiveness in enhancing visitors' knowledge and altering peoples' attitudes and behaviours (Willison 2006; Ballantyne, Packer, and Hughes 2008; but see Stewart 2002; Sellmann and Bogner 2012). This is partly because education and learning processes are interdisciplinary efforts that involve knowledge related to psychology, ecology, and pedagogy. Currently, most of the educational staff in BGs have studied biology or horticulture, but have limited capacity for exploring educational programmes from psychological and pedagogic perspectives (Willison 2006; Duvall and Zint 2007). Without appropriate evaluation, it is difficult to determine the impact of an education programme upon people's knowledge, environmental attitudes and behaviours (Carleton-Hug and Hug 2010).

People visit BGs often with purpose of accessing nature and appreciating the beauty of the landscape and the plants, rather than specifically for gaining knowledge about plants (Miller et al. 2004; He and Jin 2011). Furthermore, compared to the animals in the zoos, the plants in BGs often attract less interests from the common public, especially for children (Wandersee 1986; Kinchin 1999; Prokop, Prokop, and Tunnicliffe 2007; Schussler and Olzak 2008). However, knowledge would play an important role on people's environmental awareness enhancement (Arcury 1990; Caro, Borgerhoff Mulder, and Moore 2003; Kuhar et al. 2010; Shwartz et al. 2012). On the other hand, human's knowledge about plants is alarmingly low (Bebbington 2005) and the attitudes toward plants are not found to be always positive (Fančovičová and Prokop 2010) and this needs to be changed – research showes that practical work with live plants can be responsible for a positive change (Fančovičová and Prokop 2011). Many teaching methods are used in both formal and informal education. Some of them emphasize the importance of learning initiative (Klahr, Zimmerman, and Jirout 2011). This intrinsic motivation for learning, also known as curiosity, has been discussed in the field of education for years (Reio and Wiswell 2000; Litman and Spielberger 2003; Reio et al. 2006; Wouters, Van Der Spek, and Van Oostendorp 2008; Kang et al. 2009; Bowler 2010; Klahr, Zimmerman, and Jirout 2011). Loewenstein (1994) interpreted curiosity as a form of cognitively induced deprivation that arises from perception of a gap in knowledge or understanding.

Educators of BGs have tried many ways to motivate visitors' curiosity about plants and nature. A flexible approach to stimulate peoples' curiosity is to make them perceive their own lack of knowledge by providing them new information and sensory experience (Loewenstein 1994). One of the approaches is a practice termed 'free-choice learning'. Free-choice learning was introduced by Falk (2005) in order to replace the concepts of informal and nonformal learning. The idea of free choice emphasizes the unique nature of out-of-school environments that allows the learner to identify several learning options, in a variety of spaces, and finally, to choose a specific option, theme, or space for leaning. The concept of free choice learning thus could include all out-of-school information sources, such as museums, zoos, libraries, nature centres, and so forth (Bamberger and Tal 2007).

Studies indicated free-choice learning can lead to a behaviour change in environmental conservation, which may be due to learning providing on-site access to the knowledge, creating favourable learning environment, enhancing learner's engagement (Falk 2005), as well as stimulating a continuum of learning need afterwards (Ballantyne and Packer 2005, 2011; Falk 2005). A study focusing on the educational effect in several museums by comparing no-choice learning *vs.* different levels of choice learning also indicated that limited choice of learning could enhance the students for a deeper engagement in the learning process, and connect the visit to their own life experiences and to their prior knowledge (Bamberger and Tal 2007).

Free-choice learning has been practiced in some educational programmmes within BGs, although BG educators may not necessarily recognized the programmes have adapted this model of environmental learning. For example, a way of providing information is through a 'plant hunt' game, a modification of the traditional treasure hunt. Education programmes under or partly under the plant hunts design idea have been run in several BGs worldwide. A map called 'Discover Wakehurst' can be downloaded from the Kew Royal Botanic Garden website (http://www.kew.org/visit-wakehurst/index.htm). This map lists dozens of plants that grow in all four seasons and leads users to find them around the BG. Discovery backpacks are also available at Longwood Gardens (USA, which are designed to supplement unguided group visits. The backpacks contain magnifying glasses, maps, etc., that help different types of visitors (i.e. school groups, youth groups, scouts, and after-school groups from ages 6 to 12) experience the garden (http://www.longwoodgardens.org/Self-directedCurriculumActivities.html). In the Australian National Botanic Gardens, many educational programmes are designed to help visitors discover the connections between people, plants, and animals through inquiry-based explorations and hands-on learning experiences (http://www.anbg.gov.au/gardens/education/programs/index.html). Programmes like these should help to enhance the experiences of BG visitors and encourage active learning. However, systematic evaluation to determine how these programmes affect visitors' knowledge and attitudes towards nature is lacking.

In this study, we developed a plant hunts game called 'Discovery map' and distributed it to the visitors of XTBG of the Chinese Academy of Sciences. Using a questionnaire survey and behavioural observation of the visitors, we attempted to address the following questions: (1) whether visitors who used the discovery map (map-users) learned significantly more than visitors who did not use the discovery map (non-map-users), (2) whether map-users behaved in a significantly different manner while touring the garden than non-map-users, (3) whether visitors who used the discovery map (map-users) got significant satisfaction for the tour than visitors who did not use the discovery map (non-map-users). As a whole, we evaluated the potential of discovery maps for the enhancement of the educational function of BGs.

Methods

Study site

This study was conducted in the XTBG, Chinese Academy of Sciences. XTBG, a major Chinese botanical garden, located in South of Yunnan Province, southwest China (21°41′ N, 101°25′ E) (Qiu 2009). The garden was established in 1959 and covers an area of 1125 ha. Over 13,000 species of tropical plants have been collected and are maintained in its 38 living collections (http://english.xtbg.cas.cn/au/bi/). The western portion of XTBG (~200 ha) is the main area that is open to visitors. The interpretation system in this portion are as follows: (1) most plant species have a simple label that indicates its name, scientific name, and distribution (Figure 1(a)); (2) approximately 100 plant species have special panels that provide more detailed information about the plants (Figure 1(b)); and (3) each living collection has a panel that provides general information about the collection, including how many species are in the collection and why it was set up (Figure 1(c)). In addition, there is a visitor education centre (2200 m^2) located inside the garden where visitors can access a comprehensive and systematic introduction to the local natural history, indigenous knowledge, and tropical rainforests and their protection (He and Chen 2012) (Figure 1(d)). Unlike most city gardens that are visited primarily by local residents, XTBG is often visited by the tourists from nonlocal provinces who come to view tropical plants and tropical rainforest (Yan, Chen, and He 2010). In order to help visitors to better experience the garden, more than 50 trained local youths act as tour guides. Usually, it will take the visitors' two to three hours to visit the main part of XTBG with tour guide. Approximately 650,000 visitors visit XTBG each year.

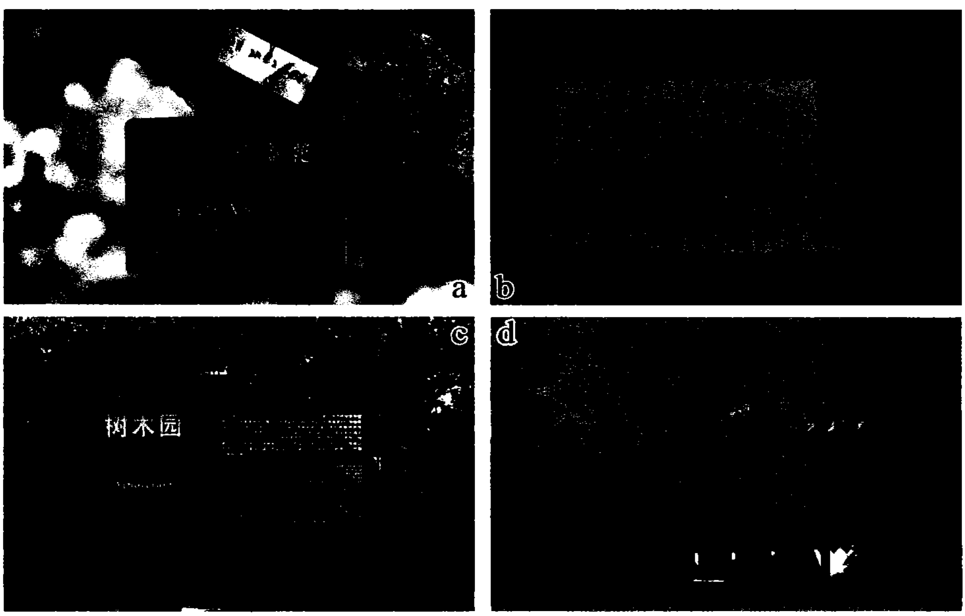

Figure 1. The interpretation system at XTBG. (a) simple label; (b) special panel; (c) living collection panel; (d) visitor education centre.

Design of the discovery map

A map of the west portion of XTBG was designed (the discovery map) and was used as an educational tool in this study (Figure 2). Ten plant species (*Bougainvillea*

Figure 2. The discovery map used in the study. On the inner page, ten species were carefully selected to be marked on the route map. These species were close to the main road of the tour trip, so they were not very hard to be found. Extraordinary roots, stems, leaves or flowers of these species were the reasons for choosing them. On the outer page, brief and attractive descriptions of these targeted plant species were shown to introduce the most interesting feature of the plant species.

spectabilis, *Tacca chantrieri*, *Pandanus tectorius*, *Anthurium andraeanum*, *Cissus sicyoides*, *Raphia vinifera*, *Hyophore lagenicaulis*, *Callistemon rigidus*, *Victoria cruziana*, *and*, *Stephania epigaea*) were carefully selected to be highlighted on the discovery map. These species were close to the main road of the tour trip, so they were not very hard to be found. They were chosen for some extraordinary features of their roots, stems, leaves or flowers.

Brief and attractive description of these species were shown on the back of the map, introducing their most interesting features (in Chinese, see Appendix 3). Half of these descriptions ended with a question, which the visitors could answer for themselves after observing the plant species. Visitors could therefore follow the route map and find the plants on the map with the aid of the included illustrations. The discovery map guided visitor exploration of the botanical garden while providing visitors with a self-directed learning opportunity. Whether, when, and how to find the plants on the discovery map was up to the visitors.

Instruments of the questionnaire

We created a two-page questionnaire (in Chinese, see Appendix 1). The following four sections were included in the questionnaire: (1) knowledge, (2) visit satisfaction (He and Chen 2012), (3) involvement with the discovery map, and (4) the participant's demographic information.

The knowledge portion of the questionnaire consisted of 17 multiple-choice questions with four possible responses (Cronbach alpha reliability coefficient is 0.6). The answers to all these questions could be found on the explanatory posters in the garden and visitor education centre. The content of the questions included such topics as: plant species, biodiversity conservation, rain forests, and the culture of indigenous ethnic groups. Importantly, none of the answers to these questions was included on the discovery map. In addition, to answer these questions, the visitors needed to read the other educational information available to them in the garden.

Three questions were used to examine visitor satisfaction. Two questions, 'Willingness to revisit' and 'Willingness to recommend the site to friends and colleagues' were assessed using 5-point Likert scales. The third question, 'Assessment of the entrance fee', was examined using a structured choice. Involvement with the discovery map was measured using the following questions: (1) did you use the discovery map? (1 = yes, 2 = no).

We collected the following demographic information from the participants: age, gender, residence, type of residence community, and education level. Other information about the visit, including number of times ever visited XTBG and whether the respondents participated in a tour led by an XTBG tour guide, was also included in the questionnaire.

Questionnaire survey

Discovery maps were given to the visitors before their visit at the main entrance of XTBG. A simple research desk was located at the main exit. During a 6-week data-collection period, 2–3 researchers approached the visitors to collect data. Weekdays, weekends, and school holidays periods were included in the sampling period. The visitors were invited to complete a questionnaire after their visit, and the aims of the research were briefly outlined. The visitors who were too young/old to read were not included in the study. Participants were recruited via a welcome poster that was placed next to the research desk.

To overcome sample bias, we: (1) distributed the samples in a 6-week period to capture a good representative of visitors to the garden as a whole, (2) when inviting people to use the discovery map, we invited the visitors who were ready to enter the garden within a fixed period; while some people did not accept our invitation (approximately 20%).

Visitor observation

We explored how the discovery map affected the way the visitors spent time during their tour using structured observations. Observations were conducted in one of the living collection sites, the 'Distinctive Plant Collection', where there is only one entrance. The single entrance allowed the researchers to easily follow the visitors. Occupying an area of 0.8 ha, the Distinctive Plant Collection is home to approximately 230 types of tropical rare and exotic flowers and trees. In this collection, there were three species that were shown on the discovery map. There were also seven interpretation panels of other species in this collection.

Observations were conducted by two researchers, who followed the unwitting visitors without interference and completed a behaviour-recording sheet for each visitor observed. One researcher observed the visitors with a discovery map in hand and the other observed the visitors without the map in every pair of visitors. To avoid sample bias, we selected the non-map-users according to the following conditions: he/she was the first individual or group member entering the collection immediately after the last observed map-user, who was the same gender as the observed map-use visitor. During the two-week experiment, observation was conducted in fixed time, from 9 am to 12 am.

The behaviour-recording sheet contained the following items: entering time, leaving time, gender, age, whether one participated in a guided tour, possession of a camera, the proportion of the collection visited, frequency of reading interpretation panels, frequency of taking photographs of people, frequency of taking photographs of plants, frequency of observing plants, frequency of discussing plant-related questions with companions, and frequency of asking tour guide questions. Visitors' age and 'the proportion of the collection visited' were estimated by the researchers. To minimize differences between the observations of the two researchers, they underwent training prior to their first observation, and both researchers have equal number of observation for both map-users and non-map-users. Since we did not allow visitors being aware of the observation all data presented is anonymous.

In the observation experiment, we collected 106 samples (53 map-users and 53 non-map-users) over two weeks.

Data analysis

A total of 969 valid questionnaires were obtained from 1151 participants; 424 of these were from map-users, and 545 were from non-map-users. Basic participant information is listed in Appendix 2. There were no significant differences for demographic aspects between map-users and non-map-users on gender, type of residence community, education level aspects, tour guide, (χ^2 test, $p > 0.05$). However, on the residence, age, and times of XTBG visited before, the two groups were significantly different.

There was only one right answer for each knowledge item, if the answer is right, get 1 score, otherwise, is '0'. The knowledge score was the sum of total scores for all the questions. The variable of knowledge score is not satisfied distribution of normality (Shapiro-Wilk statistic value is 0.988, $p < 0.001$). The three visitor satisfaction statements were scored separately. Two questions, 'Willingness to revisit' and 'Willingness to recommend the site to friends and colleagues' were assessed using 5-point scales (1 = definitely not to 5 = definitely). The third question, 'Assessment of the entrance fee', was examined using a structured choice (5 = very cheap to 1 = expensive).

Backward conditional linear regression was used to test the influence of discovery map use on the visitors' knowledge and to evaluate the association between knowledge and the demographic characteristics that were also associated with the use of discovery maps, as the backward stepwise regression model can help to extract the best subset for use in forecasting model among potential independent variables (Gelman and Hill 2007). Knowledge scores were regarded as the dependent variable, while discovery map use and visitor demographic characteristics were regarded as explanatory variables. The same method was used to test the influence of the use of discovery map on the degree of visitor satisfaction.

All calculations were performed using SPSS 20.

Results

Influence of map use on visitors' knowledge gain

Discovery map users scored significantly higher on knowledge-related questions than visitors who did not use the map, as indicated by the backward conditional linear regression (Table 1). Meanwhile, visitors with higher levels of education had significantly higher knowledge scores than those with less education. The factor 'times of XTBG visited before' was included in the selected model but its p-value was not at the 5% significant level. Other factors, such as gender, age, residence, type of residence community and visited with tour guide were not included in the selected model, implying that these factors were not associated with visitors' knowledge gain (Table 1).

Influence of map use on visitor satisfaction

The three questions regarding visitor satisfaction were treated independently. The result of backward conditional linear regression indicated that the use of discovery map had significant influence on 'Willingness to revisit', but had no significant influence on 'Willingness to recommend the site to friends and colleagues' and 'Assessment of the entrance fee' (Table 1).

Discovery map users showed a significantly higher willingness to revisit XTBG than visitors who did not use the map ($\beta = 0.066$, $p = 0.043$). Also, older visitors showed a higher willingness to revisit XTBG than younger visitors ($\beta = 0.092$, $p = 0.005$), none of the other demographic factors were included in the selected model. 'Willingness to recommend XTBG' was significantly associated with participants' age ($\beta = 0.108$, $p = 0.001$). Older visitors were more likely to recommend

Table 1. Linear regression analysis of the responses to knowledge-and visit satisfaction-related questions by map-users and non-map-users to XTBG.

Model	Knowledge[a]			SD1[b]			SD2[c]			SD3[d]		
Variable	β	t	p	β	t	p	β	t	p	β	t	p
Full model												
Map use	.093	2.864	.004**	.069	2.085	.037	.059	1.775	.076	.002	.051	.959
Gender	−.041	−1.257	.209	−.038	−1.167	.244	−.026	−.783	.434	−.060	−1.857	.064
Age	.000	−.002	.999	.083	2.181	.029	.106	2.776	.006**	−.082	−2.162	.031
Residence	−.050	−1.376	.169	.001	.031	.975	.009	.242	.809	.078	2.137	.033*
Type of residence community	.030	.935	.350	−.005	−.157	.875	−.008	−.255	.799	.044	1.367	.172
Education level	.168	4.539	.000**	.002	.064	.949	.001	.021	.983	−.015	−.393	.694
Times visited before	.055	1.623	.105	.031	.907	.365	−.011	−.311	.756	.022	.639	.523
Visit with tour guide	.064	1.860	.063	−.015	−.432	.666	−.034	−.973	.331	.134	3.897	.000**
Selected model												
Map use	.095	2.955	.003**	.066	2.024	.043*	.058	1.770	.077			
Gender										−.062	−1.910	.056
Age				.092	2.811	.005**	.108	3.287	.001**	−.085	−2.615	.009**
Residence										.069	1.988	.047*
Type of residence community												
Education level	.157	4.915	.000**									
Times visited before	.061	1.909	.057									
Visit with tour guide										.130	3.802	.000**

Indicator for satisfaction: SD 1: Willingness to revisit; SD 2: Willingness to recommend to friends and colleagues; SD 3: Assessment of entrance fee.
[a]Full model: $R^2 = 0.042$; Selected model: $R^2 = 0.035$.
[b]Full model: $R^2 = 0.014$; Selected model: $R^2 = 0.011$.
[c]Full model: $R^2 = 0.015$; Selected model: $R^2 = 0.013$.
[d]Full model: $R^2 = 0.038$; Selected model: $R^2 = 0.036$.
$*p < 0.05$; $**p < 0.01$.

XTBG to their friends or colleagues than younger visitors. 'Map use' was in the selected model of backward conditional linear regression ($\beta = 0.058$, $p = 0.077$), but its p-value was not significant. Participants' age ($\beta = -0.085$, $p = 0.009$), residents ($\beta = 0.069$, $p = 0.047$) and 'visit with tour guide' ($\beta = 0.130$, $p < 0.01$) were significantly associated with 'assessment of the entrance fee'. Younger visitors, visitors from other provinces and visitors who visited with a tour guide considered the entrance fee to be more reasonable. Gender was included in the selected model, although its p-value was 0.056 ($\beta = -0.062$).

Discovery map effect on visitors' tour behaviour

The results of observation experiment indicated that visitors with a discovery map visited the plant collection in a significantly different manner than visitors without a discovery map. The map-users tended to explore a greater proportion of the area, spend more time reading the interpretation panels, spend more time observing plants, and spent more time in plant-related discussion with their companions than non-map-user (Figure 3). There was no significant difference between map-users and non-map-users on the four demographic aspects: gender, age, participation in guided tour and possession of a camera.

Discussion

This study provided significant evidence that self-guided educational materials such as the discovery map can enhance the educational role of BGs. The discovery map enhances visitors' curiosity beyond the topics of the map; the map-users tended to spend more time and explore a greater area in the garden, read the interpretation panels more carefully, and to observe the plants more often than non-map-users. Map-users performed significantly better on the knowledge-based questions than non-map-users. And the map-users showed higher willingness to revisit the garden. Our results suggest that the plant hunts game 'Discovery map' should become a common environmental education programme to improve visitors' engagement during the visit and may enhance the effectiveness of environmental education in BGs.

The differences in visitor knowledge gain we obtained from the questionnaire survey are well explained by the result of observation experiment. In this study, the knowledge test focused on the interpretation available in the garden, not the educational material on the discovery map. These knowledge questions are mostly new to a large proportion of non-local visitors. The result of observation experiment shows that map-users tend to pay more attention on the interpretation available in the garden. It shows that free choice learning could facilitate a gain in knowledge when people visit botanic gardens.

This study indicated that providing a discovery map can be an effective and practical education tool in BGs. The advantage of the discovery maps is that it provides the visitors self-guided tours, which can be easily accommodated in most BGs while most BGs have limited human resources that could not provide sufficient tour guides to the visitors. On the other hand, such maps are only useful when the garden provides comprehensive interpretation information, as the map alone does not provide sufficient information and does not encourage an active learning process without additional information in the garden itself.

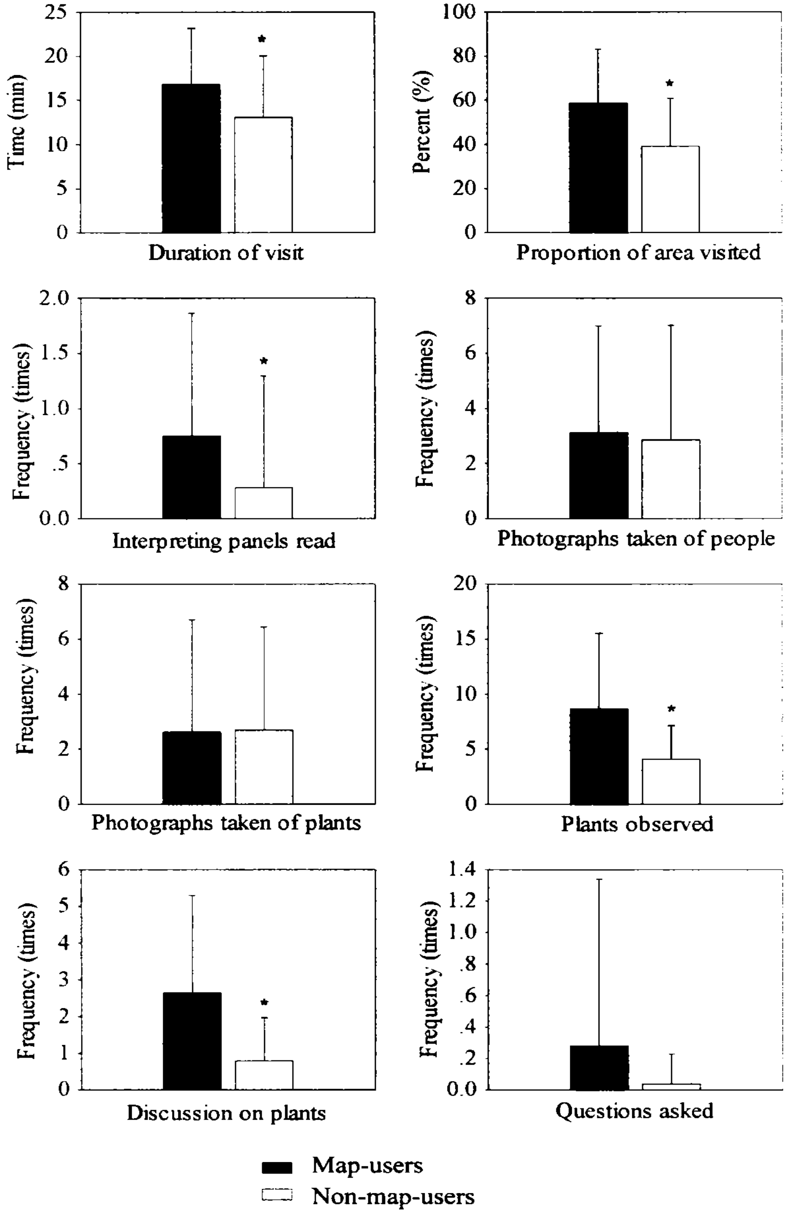

Figure 3. *t*-test results for visitor observations. *t*-test results for visitor observations indicating significant differences in mean (± SD) in the manner of visit to the Distinctive Plant Collection of XTBG between map-users (black bar) and non-map-users (white bar). *Indicates a significant difference ($n = 53$, $p < 0.05$).

Enhancing people's knowledge on plants have been discussed for a long time as a challenge for education (Bebbington 2005; Fančovičová and Prokop 2010). BGs have played an important role as informal learning sites for plant knowledge to both adults and children. As discussed in the introduction part, compared to the animals in the zoos, the plants in BGs often attract less interests from common public especially from children (Wandersee 1986; Kinchin 1999; Prokop, Prokop, and Tunnicliffe 2007; Schussler and Olzak 2008). This study, however, has shown a positive enhancement in knowledge gain simply by providing visitors' a discovery map, which indicates a great potential for BGs to better achieve their educational goal. Stewart's (2002) study in the Royal Botanic Gardens Sydney also indicated when the students actively engaged in interacting with plants, their experiences can result in long-term memories of plants and specific places at the RBGS.

The significant knowledge -gain increase for the map-users in this study itself might hold limited significance in its utility. First, no evidence indicated how long this kind of knowledge can still be retained, and how the knowledge relates to conservation attitudes and behaviour. Second, as the study did not conduct pre-test, the visitors' knowledge before the visit may also affect the results, especially for the visitors who visited the garden before. Third, no random selection for people using map in this study may also bring bias to the result. One viable alternative to the results obtained here is that map users could be motivated to learn about plants more than non-users, but this motivation was initial, i.e. it did not increase after the visit. Taking account of the rather large sample size of the study (total 969 participants), the variables above could be minor to whole conclusion. However, more studies are needed to better understand how and to what extent, this free-choice learning technology could help to enhance visitors' learning intention and gain more knowledge by the tour. Nevertheless, the differences in knowledge gain could be a good indicator for measuring the degree of engagement at BGs. The observational data of the visitors' tour behaviour also support the pattern. Educational programme and information in BGs have been criticized for its low engagement with the visitors (Kneebone 2007). Along the free choice learning framework, BGs can definitely create more active learning process in the botanic garden setting in relation to diverse notions of curiosity, learning and understanding, in order to enhance the educational functions (Zion and Sadeh 2007; Ballantyne and Packer 2011). Previous studies have also shown that, by presenting some 'marquee plants' in maps, visitors' attention could be significantly enhanced (Wandersee and Schussler 2001; Sanders 2007; Nyberg and Sanders 2014).

In conclusion, the plant hunts game 'Discovery map' undertaken in this study provided a free-choice learning process to the visitors and had shown a significant effect on increasing the visitors' engagement and thus enhance its educational function. Designing some discovery maps with different themes, such as distinctive plants, endangered plants, flowering plants and so on could be a good way for BGs to improve visitors' visit experience. According to seasonal changes or transforms of education topics, various discovery maps could provide regular visitors more opportunities to rediscover the BG and the plants. The learning theoretical support for the discovery map design also could be used in other education programmes. Educational programmes within BGs should incorporate learning theory in the programme design more often and include appropriate quantitative evaluation of those programmes.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix 1. Survey of botanical garden visitors

Dear friends, I am a graduate student of Xishuangbanna Tropical Botanic Garden. We are conducting a survey on the effectiveness of a discovery map. This survey will help us to design a better guide map for the botanical garden. It will take 5–10 min. Sincere thanks for your help.

Part I

1. Which of the following plants is a 'living fossil'?
   A. *Cycad* B. *Palm* C. *Parashorea chinensis* D. *Bombax malabaricum*
2. Which species dies after it flowers and produces fruit?
   A. *Parashorea chinensis* B. *Raphia vinifera*
   C. *Bombax malabaricum* D. *Caesalpinia pulcherrima*
3. Which of the following plants produces fruit that can temporarily change a person's sense of taste?
   A. JackfruitB. Miracle fruit C. Canistel D. Passionfruit
4. People often say 'Wuhuaguo' (fig) refers to which of the following plants?
   A. *Palm* B. *Ficus* C. *Baccaurea* D. *Canistel*
5. Which of the following scientists is the founder of the Xishuangbanna Tropical Botanical Garden?
   A. Cai Xitao B. Wu Zhengyi C. Hu Xianxiao D. Chen Huanyong
6. Which phenomenon is not unique to the tropical rainforest?
   A. Strangulation B. Cauliflory C. Board root D. Evergreen

7. Which species of plant's leaves was the Dai character written on?
   A. *Caryota urens* B. *Corypha umbraculifea* C. *Ficus religiosa* D. *Saraca dives*
8. How tall can a *Parashorea chinensis* grow?
   A. 20 meters B. 40 meters C. 80 meters D. 100 meters
9. The main strangling tree in Xishuangbanna rainforest is:
   A. *Samanea saman* B. *Parashorea chinensis* C. *Caryota urens* D. *Ficus*
10. Which of the following trees has the largest board root in the world?
    A. *Tetramelaceae* B. *Elaeocarpus apiculatus*
    C. *Heritiera littoralis* D. *Ficus altissima*
11. Which of the following areas have NO tropical rainforests?
    A. Africa B. Central America C. North America D. South Asia
12. Worldwide, tropical rainforest areas account for which proportion of land area:
    A. 7% B. 17% C. 27% D. 37%
13. Which of the following butterflies is a national first-level protected animal and is endemic to
    China?
    A. *Kallima inachus* B. *Teinopalpus aureus* C. *Cethosia cyane* D. *Achillides bianor*
14. The general trend of the world's biodiversity is best described as:
    A. In sharp decline B. Destruction is under control
    C. Progressively increasing D. Species no longer become extinct
15. Which of the following statements best describe the characteristics of a tropical rainforest?
    A. The plants are very dense.
    B. There are many kinds of species in a region.
    C. The plants are very big.
    D. There are many conifer species in the rainforest.
16. Which of the following statements about rainforests is incorrect?
    A. China has no typical tropical rainforests.
    B. Tropical rainforest hold a great amount of plant resources that be critically important to future sustainability of human beings.
    C. Tropical rainforest trees occupied different spatial levels than those in temperate forests.
    D. Worldwide tropical rainforests are currently being damaged enormously.
17. Which of the following statements about Xishuangbanna Tropical Botanical Garden is incorrect?
    A. It is subordinate to the Chinese Academy of Sciences.
    B. It is a scientific research institution.
    C. It covers an area of approximately 90 ha.
    D. It is engaged in biodiversity conservation.

Part II

1. If possible, will you visit this botanical garden again?
   A. Definitely not B. Probably not C. Uncertain
   D. Probably E. Definitely
2. Would you like to recommend XTBG to others?
   A. Definitely not B. Probably not C. Uncertain
   D. Probably yes E. Definitely yes
3. What do you think of the entrance fee for XTBG?
   A. Very cheap B. Cheap C. Reasonable D. High E. Expensive
4. How many times have you visited this botanical garden?
   A. This is the first time B. Two or three times C. More than 3 times
5. Did you use the 'Discovery map'?
   A. Yes B. No
   (If you choose 'No', then you do not have to answer the next 2 questions.)

6. How many species marked on the 'Discovery map' did you find?
   A. Less than 3 B. 3 to 5 C. 5 to 9 D. All of them
7. How did you find the 'Discovery map'?
   A. Very helpful B. Helpful C. Little help D. No help

Part III

1. Your gender : A. Male B. Female

2. Your age: ________

3. Residence: ________ province

4. Area: A. City B. Suburbs C. Country

5. Education level: A. High school or below B. College or university

   C. Graduate school or above

6. Guided by the tour guide of XTBG? A. Yes B. No

7. If you wish, please leave your contact information here: ______________________________

Thank you for your cooperation.

Appendix 2. Demographic information of visitors to XTBG with and without a discovery map

	Map-user	Non-map-user	All participants
Gender			
Male	228 (53.9)	299 (55.1)	527 (54.6)
Female	195 (46.1)	244 (44.9)	439 (45.4)
Age (years)			
10–19	163 (38.4)	164 (30.1)	327 (33.7)
20–29	103 (24.3)	163 (29.9)	266 (27.5)
30–39	92 (21.9)	123 (22.6)	216 (22.3)
40–49	46 (10.8)	75 (13.8)	121 (12.5)
≥50	19 (4.5)	20 (3.7)	39 (4.0)
Residence			
Local province	136 (32.2)	214 (39.3)	350 (36.2)
Other province	287 (67.8)	330 (60.7)	617 (63.8)
Area			
City	380 (90.5)	507 (94.2)	887 (92.6)
Suburbs	21 (5.0)	19 (3.5)	40 (4.2)
Country	19 (4.5)	12 (2.2)	31 (3.2)
Education level			
High school or below	167 (39.6)	176 (32.5)	343 (35.6)
College or university	231 (54.7)	329 (60.8)	560 (58.2)
Graduate school or above	24 (5.7)	36 (6.7)	60 (6.2)
Times of XTBG visited before			
First time	380 (89.8)	461 (84.6)	841 (86.9)
Two or more visits	43 (10.2)	84 (15.4)	127 (13.1)
Tour guide			
With	267 (63.0)	315 (57.8)	582 (60.1)
Without	157 (37.0)	230 (42.2)	387 (39.9)

Note: Values are number of participants (percentage).

Appendix 3. The main part of the Discovery Map

Plant	Brief introduction
Bougainvillea spectabilis	Have you seen the glorious Bougainvillea flowers? If you look closely, you will find that the 'flower' actually is not a real petal, it is sepals. The real flower is the little white part in the middle, which the pollinators will visit. So the Bougainvillea's 'flower' botanically is actually a leaf. Bougainvillea flowers use its colorful leaves, which function as a flower, to attract pollinators
Tacca chantrieri	Have you seen the whisky black Tacca flowers? In the wild, flowers are always in red, yellow or white color, while the black ones are rare. Tacca is black color flower with amazing whisk, which looks like the tiger face. Do you wonder why Tacca has chosen the black color instead of other insect-attracting colors?
Pandanus tectorius	Have you seen the amazing prop roots of Pandanus in the tropical forest? Geologically, Xishuangbanna was once at the seashore millions of years ago. Pandanus trees grew along the seashore with supporting roots for breathing in the ancient time, and survive until now. So Pandanus is living fossil for the geological change in Xishuangbanna after its vegetation was successively evolved to rainforest
Anthurium andraeanum	Have you seen the red candles-like Andraeanum? The yellowish candle is not its petal actually, but sepal. The bright red sepal attracts the insect for pollination. The Andraeanum flower is called spathe in botany, which is a typical characteristic of Araceae family
Cissus sicyoides	Have you seen the screen-like vine? The splendid and suspending screen is actually its aerial root. The new root is red, which then changes to light green later and grow into the earth at last. Due to its beautiful roots, the *Cissus* is widely planted as a garden plant
Raphia vinifera	Look up the tall palm tree. It has a very huge 'elephant trunk'. This is the famous elephant trunk palm. Actually, the 'elephant trunk' is the palm's multiple fruits. This palm normally could live up to 20 years old. This species blossom once in its lifetime. When you see the huge 'elephant trunk', it means the tree almost finishes its life
Hyophore lagenicaulis	Look at this bottle-like palm tree. You can enjoy the great biodiversity in the kingdom of plants. This palm tree is short and fat, attracting the public very much
Callistemon rigidus	Have you seen that tube-brush-like flowers? It is stiff bottlebrush, originating from Australia. All its little flowers gather together for advertising and attracting the insect for effective pollination. Interestingly, the inflorescence just looks like a bottlebrush. This special part makes it very remarkable for both insects and the public. Could you find what kinds of insects have been attracted to the bottlebrush flowers?
Victoria cruziana	Have you seen the gorgeous gait water lily? This big water lily was originally introduced from Amazon, which has very big leaves. The leaf cell was filled with air, and very strong, which even could support a 20–30 kg child
Stephania epigaea	Have you seen the root of Stephania epigaea? Most people think that roots should grow in the soil, but not Stephania. The Stephania root grows out of soil, looking like a turtle lying on the ground. Literally, Chinese people called it 'mountain turtles'. Do you agree or not?