Ecological sustainable significance of rain garden design in Lingnan primary and secondary schools from foreign cases

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Abstract. Based on the research of the rain garden in Mount Tabor middle school, Nueva primary school, and Delta North Delta school district, this work summarized the design strategy and ecological sustainable significance of rain garden in the case from three aspects: design method, educational benefit, and ecological benefit. Finally, the design approach of rain garden in Lingnan primary and secondary schools and its significance to the sustainable development of ecological education and ecological protection were proposed.

1. Research Background and Current Situation of Rain Garden in Lingnan Primary and Secondary Schools
As a specific environmental region in China, the Lingnan region is hot in summer and warm in winter, wet and rainy in spring and autumn, and the rainy season is long and accompanied by typhoons and thunderstorms. Flood damage caused by rainstorms also occurs frequently. Too much hardened ground makes rainwater unable to seep down, forming a large area of water around and inside the campus, and discharging non-point source pollutants into the campus pipes. On the other hand, the water consumption on campus is large and diverse, such as toilet water, cleaning water, irrigation water, etc. Therefore, there is a large demand for water resources. Therefore, it is particularly important to build rain garden in Lingnan primary and secondary schools. Reducing the waste of campus water resources, reducing the pressure of school drainage, reasonable storage and utilization of rainwater will bring benefits to the campus environment and study life. At the same time, it is of great significance to enhance the awareness of rainwater resources utilization for primary and secondary school students, and promote the education of ecological protection through the construction of rainwater garden, thus establishing the ecological concept of sustainable development for teenagers [1].

2. A Case Study of Rain Garden in Foreign Excellent Primary and Secondary Schools
The author summarized the excellent overseas rain garden design cases in the recent ten years, which mainly come from the American Society of Landscape Architects (ASLA) and international landscape architecture design awards (Table 1). In different countries, design scales and climatic conditions, rain garden has been widely used in campus [2]. In these excellent cases, it should be pointed out that the university campuses are not considered as the research object of this work. Some of the cases are small-scale rain garden design (i.e, the rain garden in a single campus), while others are large-scale rain garden design (i.e, the rain garden design of the whole campus or the continuous development or the green rainwater infrastructure design with rain garden). The author selects three cases that are similar to the
climate characteristics and application fields in Lingnan region, and discusses and studies the overall design methods and strategies, thus offering reference and experience inspiration for the construction of rain gardens in Lingnan primary and secondary schools.

### Table 1. Rain garden in foreign excellent primary and secondary schools

| Time   | Name                                      | Location                | Type of site   | Climate conditions                       | Country of origin |
|--------|-------------------------------------------|-------------------------|----------------|------------------------------------------|-------------------|
| 2007   | Mount Tabor middle school rain garden     | Portland, Oregon        | Secondary schools | Mediterranean climate                    | America           |
| 2009   | Arizona State University Institute of Biology | Tempe, Arizona         | University campus   | Subtropical continental arid and semiarid climate | America           |
| 2010   | Nueva primary school                      | Hillsborough, California | Primary schools   | Mediterranean climate                    | America           |
| 2010   | Sonoran desert landscape laboratory       | Tucson, Arizona         | University campus   | Subtropical desert climate               | America           |
| 2012   | Delta North Delta school district rain garden | Delta, British Columbia | Primary schools   | Temperate oceanic climate                | Canada            |
| 2016   | University of Pennsylvania rain garden     | Pennsylvania           | University campus   | Mainland climate                         | America           |

2.1. Mount Tabor middle school rain garden.

The rain garden in Mount Tabor primary and secondary school was designed and built by landscape architect Kevin Robert Perry in the summer of 2006. The rain garden is one of Portland's premier examples of innovative rainwater management, and received the ASLA overall design honor award in 2007 [3].

2.1.1. Design method. Portland, Oregon, is located in the western United States. Mount Tabor middle school is an environmentally sustainable school in the area. The rain garden was originally located on an underutilized asphalt floor parking lot. Before the rain garden was built, the adjacent teaching building and playground were very hot in summer due to the parking lot was not covered by vegetation (Fig. 1). The designer not only turned the asphalt parking lot into green space, but also provided shading and cooling functions for the classroom through artistic transformation. At the same time, it was used to deal with the small rainstorm in the area. It is mainly used to infiltrate rainwater, control rainwater runoff, purify water quality and recharge groundwater, which is conducive to students' learning and rainwater management (Fig. 2). The rain garden covers an area of about 190 square meters and, together with other catchments, dredges part of the surface runoff from the school's roof, playground, parking lot and road surface. When the rainwater enters the garden, plants and soil will work together. The depth of rainwater runoff in the garden is 20cm, and when the rainwater exceeds this depth, it will enter the municipal drainage pipe connected with it. When there is rainfall, the rain garden will completely infiltrate after several hours at a rate of 5-10cm per hour (Fig. 3).
2.1.2. Design benefits. There is also a 0.7m sand gravel corridor in the garden, which connects the two ends of the rain garden. Visitors can see the rainwater flow into the rain garden. It also serves as a protection channel for later garden maintenance [4]. With regard to plant configuration, the designer also fully considered the color and texture collocation of different plants (Table 2).

Table 2. Plant configuration of Mount Tabor middle school rain garden

| Plant type                              | Name                                                                 |
|-----------------------------------------|----------------------------------------------------------------------|
| **Basin plantings**                     | Gold Band Sedge, New Zealand Orange Sedge, Elks Blue Rush, Big Blue Lilyturf, California Gray Rush, Cinnamon Sedge, Ice Dance Sedge |
| **Perimeter shrubs and ground cover**   | Kinnikinnick, Cascade Oregon Grape, Moon Bay Nandina, Little Rascal Holly, Silver Princess Euonymus |
| **Deciduous and conifer trees**         | Quaking Aspen, Tupelo Tree, Douglas Fir                               |
Through rain garden, students learn about sustainable rainwater management. Its rain garden system offers natural treatment methods for rainwater runoff of the whole school, and also makes students feel the importance of nature and sustainable development. The rain garden mainly focuses on solving the problems of environmental deterioration and rainwater drainage caused by hard ground in the campus. According to statistics, the site has collected about 1.9 million liters of rainwater runoff [5]. Through landscape design and rain garden technology to improve the campus environment, visual rainwater drainage infiltration process can also play an ecological education role for students to a certain extent. Also, small-scale selection and design can offer good enlightenment and reference for other primary and secondary schools with similar situations.

2.2. *Nueva primary school.*

The project, located in California, USA, won the 2010 ASLA comprehensive design honor award. Nueva primary school combines the ecosystem and rainwater collection, and then applies it to the primary school campus. Students also have a certain degree of participation in the landscape, so that they can feel a more unique sense of ownership. Nueva primary school realizes the principle of sustainability through educational space, creates outdoor environment for children to participate in the local ecosystem cycle process and learn relevant ecological courses [6]. With regard to rainwater treatment, Nueva primary school skillfully designed rainwater collection as a landscape facility for teaching and entertainment, and further carried out sustainable ecological education and water resources protection education for primary school students through the design of rain garden.

![Diagram of Nueva primary school](https://www.nuevaschool.org/)

**Figure 4.** Plan of Nueva primary school (Source: [https://www.nuevaschool.org/](https://www.nuevaschool.org/))

2.2.1. **Design method.** In Nueva primary school, rainwater management is taken into consideration. There are visible rainwater ditches in the atrium square and on both sides of the teaching building, which can not only see the rainwater flowing into the plant filtration area, but also reflect the seasonal changes...
of the environment. This will effectively mitigate the surface runoff during the rainy season without losing sight (Fig. 4). The local plants used in the campus are closely integrated with the local ecosystem. This design method not only solves the ecological and aesthetic problems in the campus, but also reduces the water consumption in the campus by 53% compared to the previous ones (Table 3). On the other hand, Nueva primary school also uses an intelligent irrigation control system combined with rainwater collection, which combines rain garden with rainwater resource reuse [7].

Table 3. Plant configuration of Nueva primary school

| Plant type     | Name                                                                 | Picture |
|----------------|----------------------------------------------------------------------|---------|
| Native plants  | Muhlenbergia rigens, Symphoricarpos mollis, Sisyrinchium bellum, Juncus patens, Woodwardia fimbriata, Carex tumlicola, Festuca rubra, Green roof habitat plantings, Quercus agrifolia |         |
| Non-native plants | Bambusa oldhamii, Heuchera maxima, Gingko sp., Preserved Quercus agrifolia Heritage Oak, Preserved Cupressus macrocarpa |         |

2.2.2. Design benefits. Different from other types of rain gardens, Nueva primary school pays more attention to the user's personal experience, the change of time and the change of season when building rain gardens and other green rainwater infrastructure, which makes the whole design have a long-term influence (Fig. 5). It is necessary for students to understand and learn about water resources and environmental protection and pay attention to biodiversity in the campus with sustainable design.

Figure 5. Nueva primary school (Source: https://www.nuevaschool.org/)

Nueva primary school not only has a rain garden in the campus, but also the whole campus is designed under the concept of sustainability. Compared with middle school campus, primary school campus has more constraints and particularity, and thus it is particularly important for younger students to learn relevant knowledge from the real ecosystem. The recreational landscape facilities and children's rain garden are also the most direct and quick way for children to enter and understand nature.

2.3. Delta North Delta school district rain garden.

North Delta school area, located in Delta city, British Columbia, Canada, has more than 20 primary and secondary schools, which has been developing for 14 years since 2006. At first, a local primary school tried to install rain gardens in the city. Since then, all primary schools in the area have installed rain gardens with the frequency of increasing 1-2 every year. Currently, 29 schools have completed the construction of rain gardens. At the same time, the Canadian climate and environmental protection department has specially developed a curriculum education section for each school to improve the participants' understanding and learning of the ecological environment, regional watershed and hydrological relationship, thus ensuring the long-term operation of rain gardens in each school. In 2019, it was selected as a national important campus rain garden case by Canadian climate department (Fig. 6) [8].
2.3.1. **Design method.** The project can be seen as a relatively macro design case of campus rain garden, which is different from other campus rain gardens in that: 1) the whole rain garden design and construction project is sustainable. The local authorities will take the whole plan as a ten-year stage, and arrange and plan the 20-year rain garden construction project. The ultimate goal is to complete the construction of rain garden for all schools in the area and surrounding communities. 2) Rain garden construction is carried out in primary and secondary school campuses and communities. Apart from the teachers and students in the school, there are also volunteers from the community and students' parents in the late construction and maintenance process, who jointly complete the whole continuous construction of the campus rain garden (see Fig. 7). 3) Multi-party cooperation design. Multi-disciplinary and multi-professional participation is also one of the characteristics of the project. The city has coordinated workers of different professions, including urban engineers, planners, gardeners and forestry workers. Engineers are responsible for earthwork, installation of inflow equipment, safety overflows.

![Delta Rain Gardeners Classroom Program](https://www.deltasd.bc.ca/)

**Figure 6.** Delta rain garden instruction manual (Source: [https://www.deltasd.bc.ca/](https://www.deltasd.bc.ca/))

2.3.2. **Design benefits.** Regarding education, the establishment of the rain garden has led the local environmental protection ministry and the education ministry to develop a curriculum module for students based on ecological protection and storm water management, thus educating children and enabling them to participate in the maintenance of rain garden. Every year, the maintenance of the rain garden will be assigned to a class of students. Delta city will often invite local scholars and residents to

![Teachers and students work with community volunteers and social professionals to restore the rain garden](https://www.deltasd.bc.ca/news-events/news/)

**Figure 7.** Teachers and students work with community volunteers and social professionals to restore the rain garden (Source: [https://www.deltasd.bc.ca/news-events/news/](https://www.deltasd.bc.ca/news-events/news/))
give lectures on environmental issues and hold ecological seminars in the school district to ask them to put forward environmental issues and suggestions. Unlike the first two cases, the construction of rain garden in the Delta school district is an ongoing project. It puts forward the planning plan for the next 20 years. Every school will build rain garden, and yet there are some differences. The schools within the school district are responsible for connecting the community and professionals from all walks of life.

2.4. **Horizontal comparison of cases.**

Accordingly, the site properties and forms, underlying surfaces, rain garden design features, plant configuration features, and emphasis in the design of the above three cases are summarized and compared horizontally, as shown in Table 4.

| Name                     | Mount Tabor middle school rain garden                        | Nueva primary school                            | Delta North Delta school district rain garden |
|--------------------------|--------------------------------------------------------------|-------------------------------------------------|---------------------------------------------|
| Site attributes          | Campus garden                                                | Primary schools                                 | Large school districts                      |
| Site form                | Small campus landscape                                       | Campus master plan                              | Large area multi-area campus landscape      |
| Underlying surface       | Asphalt parking, hard ground, roof                           | Impervious campus roads, roofs                  | Community road and campus road              |
| Rainwater guidance       | Rainwater drains, municipal plumbing                         | Rainwater collection, vegetation filtration,    | Vegetation filtration, municipal pipelines  |
| Rain garden type         | Small central garden located in the centre of the school     | Medium campus rainwater infrastructure          | Distributed multi-area rain garden         |
| Vegetation configuration characteristics | Native plants resistant to moisture and drought | Native plants and non-native plants | Native plants |
| Design focus             | Having a certain educational demonstration function          | Sustainable campus design, education and fun,   | With the school as the point and the community as the aspect |
|                          |                                                              | child-friendly                                  |                                              |

3. Ecological Sustainable Significance of Rain Garden Design in Lingnan Region of China from Foreign Cases

3.1. **Sustainable rain garden design form.**

From the case analysis, it is concluded that the rain garden form is not a single ordinary garden, and thereby it is necessary to choose the appropriate, targeted and sustainable form of rain garden. Only according to the characteristics of the site, the needs of users and the complete concept of sustainable ecological rain garden can maximize the benefits of rain garden. Therefore, the choice of sustainable rain garden form in such a specific scene of primary and secondary schools, not only has a positive significance in the protection of ecological environment, but also has a positive role in promoting students to understand and learn ecological knowledge.
3.2. Following the design guidelines for sustainable development.

In order to ensure the function of rain garden, the sustainable design guidelines of rain garden should be formulated according to the campus culture, development direction and campus characteristics. On the one hand, it should consider the corresponding objective conditions, select and formulate the design guidelines suitable for rain garden in the process of rain garden design, which can more accurately and efficiently complete the construction of rain garden. On the other hand, primary and secondary school campuses also have different characteristics, training ideas and other subjective conditions. Combined with the characteristics of Lingnan area, choosing more suitable design guidelines will also add more colors to the campus itself.

3.3. Paying attention to the sustainable educational benefits of rain garden.

With the development and progress of the times, ecological education has increasingly become the focus of youth education. The rain garden in primary and secondary schools can not only solve the actual rainwater problem, but also provide students with outdoor places for sustainable ecological education. Due to the lack of suitable outdoor environment and venue model in the campus, there are still many primary and secondary school students in China still stay on the textbooks for the study of environmental protection and ecological concepts. On the one hand, only by "moving" the classroom to the outside, can students understand nature better. On the other hand, primary and secondary school students need to cultivate the awareness of environmental protection to save water and rationally use rainwater resources. Therefore, the educational benefits provided by rain garden play a significant role in primary and secondary schools.

3.4. Promoting the sustainable development of campus ecology and popularizing the concept and measures of sustainable development.

Carrying out sustainable development education can help primary and secondary school students better understand the close relationship between environment and economic, social and cultural activities, and understand the relationship between human society and the earth environment they live in. Also, it can realize the benefits of individual behavior to promote balanced development in all aspects, and mobilize primary and secondary school students to protect the environment and biodiversity. On the one hand, the construction of rain garden plays an essential role in the utilization of rainwater and the protection of campus ecological environment. On the other hand, rain garden also plays a supporting role in natural science education, moral and aesthetic education. This enables primary and secondary school students to cultivate the sustainable development awareness of caring for nature and experiencing nature in the process of building and maintaining rain garden.

4. Conclusion

Rain garden has been developed at home and abroad due to its advantages of simple construction, low cost, convenient maintenance, natural beauty, etc. Under the background of promoting ecological civilization construction, sustainable development concept and natural ecological education, the rain garden in Lingnan primary and secondary schools has broad prospects for development. Through the design cases of foreign excellent rain garden, new ideas and suggestions are offered for the development and application of rain garden in Lingnan primary and secondary schools.

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