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Increasing Sustainability Literacy for Environmental Design Students: A Transdisciplinary Learning Practice

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Abstract: Nowadays, the urban water system is facing many challenges which affect the sustainable development of society. This requires higher education institutions to develop people with a diversity of knowledge and complex problem-solving capacities. This paper presents a practical case of transdisciplinary learning for junior students of environmental design at NingboTech University (Ningbo, China). The course "Environmental Engineering and Technology" ran from 1 March to 24 April 2022. A total of 25 students were instructed in the theories of urban water environmental engineering and then worked in groups to complete a design project for a river ecological restoration. The outcomes were analyzed from the perspective of combining engineering and landscape design. At the end of the course, students volunteered to take an online questionnaire about course evaluation. Students responded highly positively to the course, achieved growth in sustainability literacy, and developed skills in transdisciplinary learning. It also confirms the importance of outdoor education and project-based teaching. Additionally, the lowering of the requirement for mathematical skills through the internet tools usage and the formation of multidisciplinary teams are expected to improve future teaching outcomes. These results provide new insights for educators into the integration of the disciplines between design and engineering.

Keywords: environmental design; eco-environmental engineering; transdisciplinary learning; sustainability; water ecological restoration; outdoor education; project-based teaching

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1. Introduction

Pollution, unsustainable land use, infrastructure, water management, as well as poor spatial planning lead to a number of serious water-related challenges, including floods, mudslides, land degradation, contaminated water, and water scarcity [1–3]. Issues ensuing from unsustainable human practices are aggravated by climate change and new weather patterns [4]. Additionally, stress on aquatic ecosystems will impact the capacity of oceans, lakes, and wetlands to act as carbon sinks, as well as driving mechanisms that lead to a net increase in greenhouse gas emissions [5,6]. Both the risk of feedback loops that accelerate climate change and the immediate impacts of water-related challenges on vital resources point to the urgency of sustainable land and water management. Traditional approaches to deal with water issues have focused on grey infrastructures, such as dams or reinforcing river banks. However, it has become increasingly clear that such approaches instead tend to aggravate the problems [7,8]. Since the 1960s, some highly influential theories and practices, including the sustainable drainage system (SuDS, UK) [9], low impact development (LID, USA) [10], water sensitive urban design (WSUD, AUS) [11], Water Framework Directive (WFD, EU) [12], and Nature-based Solutions (NbS, IUCN) [13], have emerged. These theories and practices emphasize systematic and ecological approaches rather than mere engineering measures to manage water resources and enhance their ecological, social, aesthetic, and cultural value [14].

Compared to developed countries, the sustainable management of the urban water systems of China is at an early stage. In 2014, the government of China promoted the "sponge city" construction based on LID technologies [15]. The sponge is a metaphor for the elastic regulation of water. It involves building hydro-ecological infrastructures across various scales, from infiltration wells to rivers and lakes, increasing the natural migration and purification of water and enhancing the overall service function of the aquatic ecosystem [16]. Since the history of sponge city construction is too short, there is a lack of related majors in the higher education systems of China that can train relevant specialists. Usually, these projects are designed in two forms [17]: (1) engineers (mainly involving water supply and drainage science engineering, environmental engineering, and water engineering) provide a blueprint and then supplement aesthetic elements with the help of landscape architects; and (2) landscape design agencies independently create them. However, due to the lack of relevant engineering knowledge and sustainability literacy, landscape architects often automatically apply the standard sponge facility specifications, resulting in poor landscape effects and functionality.

One of the most critical missions of higher education institutions (HEIs) is to train students to assist with the development of society [18]. Beginning in 2012, environmental design became an available undergraduate major in Chinese colleges and universities. As an essential part of the design of human communities, it covers many fields such as architectural engineering technology, humanities, arts, and urban landscape, mainly for indoor and outdoor living environment design research and practice. With a combination of arts, humanities, and engineering, environmental design is expected by educators to provide a holistic, human-centered, and sustainable solution for architecture, landscape, urban planning, and commercial exhibition [19]. However, the current curriculum of environmental design majors emphasizes the aesthetic effect of design more than environmental requirements, and students' abilities often fail to meet the abovementioned expectations. Researchers recommend new practices to improve learning outcomes, for example, McDermott et al. [20] suggest that place-based learning may be used as an effective method to bridge real-world problems and academic theories, and Dong [21] believes the project-based teaching model could promote student training to solve local problems.

Landscape architecture is one of the two principal directions of environmental design at NingboTech University (Ningbo, China). The university offers "Environmental Engineering and Technology" as a required course for junior undergraduates. The course integrates the mindsets, knowledge, and skills of urban water engineering into landscape design. The purpose is to increase the sustainability literacy of students that would be involved in solving complex environmental issues in the future. This paper introduces this course's organization, outcomes, evaluation, and how it can be improved. It provides a practical case of transdisciplinary learning across design and engineering.

2. Context and Methods

2.1. Course Background

NingboTech University is a comprehensive undergraduate institution in China, thus facilitating transdisciplinary learning between different colleges. A total of 25 juniors participated in this "Environmental Engineering and Technology" course. They came from the School of Design, majoring in environmental design, and were guided by a teacher (Jianqing Ma) from municipal and environmental engineering. Students have studied design content, such as landscape architecture design, interior environment design, architectural drawing, etc., but have not studied engineering courses. The course started on 1 March 2022 and ended on April 24th, for a total of 64 lessons over 8 weeks. As the course is offered for the first time at NingboTech University, the students' learning outcomes and feedback are very important to the evaluation and improvement of the course.

2.2. Course Objectives

The course "Environmental Engineering and Technology" focuses on the protection and ecological restoration of the urban water environment related to landscape design. This course aims to give students an understanding of the principles and methods of eco-environmental engineering and provides practical skills to improve the quality of urban water systems. Content and activities are intended to help future practitioners or researchers achieve effective communication and cooperation with people from different professional backgrounds and integrate sustainable concepts into their design works, to restore healthy ecosystems for the mutual benefit of humans and nature [22].

2.3. Course Organization

The eight-week course (64 lessons) includes theoretical learning and design practice sections. The organizational framework of this course is presented in Figure 1. In the first part (32 lessons), a total of 25 students were instructed in the current water issues and related engineering technologies. The main teaching methods include the following:

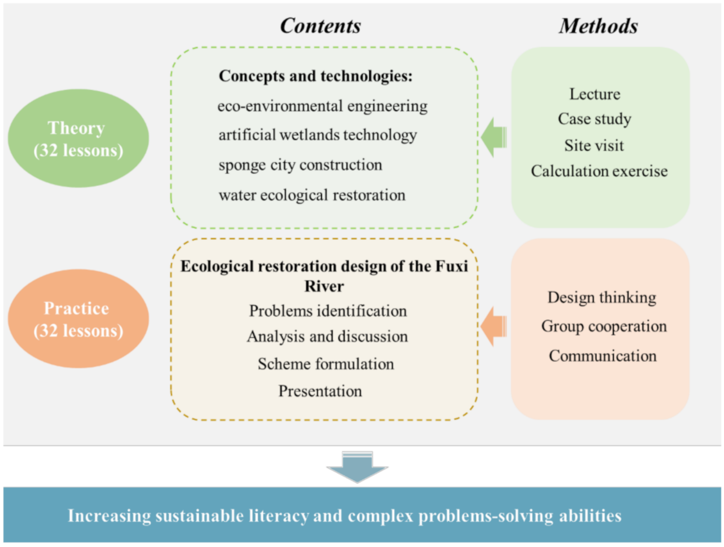

Figure 1. Course organization of "Environmental Engineering and Technology".

(i) Lecture: Face-to-face teaching and online lectures introduce the basic knowledge and recent development of eco-environmental engineering, artificial wetlands technology, sponge city construction, and water ecological restoration.

(ii) Case study: A well-established method to help students improve their problem-solving and critical-thinking skills is used by exposing them to several real scenarios [23,24]. Students have group discussions and utilize previous knowledge to answer questions asked by the teacher. For example, in the Tongxin River restoration case, students are asked to discuss the relationship between water quality and ecosystems, water problems and their causes, and the corresponding treatment measures. In another case involving the Portland Rain Garden, students are asked to identify landscape elements and their role in rainwater management.

(iii) Site visit: Ningbo Yinzhou Wetland Park uses ecological engineering and sponge city construction technology to regulate and purify rainwater and successfully realizes the harmony between artificial and ecological elements. An engineer (Shanghai Aquatic Environmental Engineering Co., Ltd., Shanghai, China) explains different aspects of the park. Students have the opportunity to see the project's actual landscape effects and sustainable facilities, which will be applied to their subsequent practical work.

(iv) Calculation exercise: Learn the calculation of constructed wetland size and the storage capacity of sponge facilities.

In the second half of this course (32 lessons), students freely team up in ten groups and complete an ecological restoration design of the Fuxi River on the campus. The design thinking model adapted from Wever [25] and Sung [26] was introduced into the project. This model allows a holistic understanding of complex issues and generates engineering solutions that are more human-centric and sustainable [27]. The teacher provides essential information about this river, including the water quality, related standards and atlas, CAD drawings of the campus, and the existing water treatment facilities. The students work in groups and make field trips to analyze the causes of river water pollution and select suitable sites and technologies for design. Finally, the students formulate a comprehensive scheme to improve water quality and landscape effects. A list of required outcomes includes the following: (a) A manual including the necessary status analysis, design objectives, schemes, and methods; (b) CAD drawings of the general layout and sections; and (c) Landscape renderings. At the end of the course, each team gives a presentation to demonstrate and illustrate their design results. The design outcomes were analyzed from four aspects: the status analysis, the selection of the restoration scheme, the landscape design effect, and drawing quality.

2.4. Evaluation Method

After the course, an online survey was used to discover whether the course was fulfilling its objectives and where teaching quality can be improved [28,29]. The questionnaire was set up regarding similar courses [30], including nine quantitative scoring questions on a 5-point scale and three qualitative questions, to obtain comments and suggestions about the course. The listed questions in the survey are provided in Table 1, and the detailed information of the questionnaire can be found in Text S1 of the Supplementary Materials. At the end of the course, the questionnaire was sent out through a mini app (https://www.wjx.cn, accessed on 4 August 2022), and students participated in the survey voluntarily and anonymously. In the questionnaire, the students were informed that the relevant data would be used for the analysis and improvement of the course, and the writing and publication of the paper. Among the 25 students, 22 completed the questionnaire. The mini app automatically gives statistical results that can be found online (https://www.wjx.cn/report/176755485.aspx, accessed on 4 August 2022). The average scores of Q1–Q9 were then calculated using these results. The achievement of course objectives is quantified by scores (out of 5).

Table 1. Student survey questions summary.

	Questions (A Five-Point Scale is Used for Q1–Q9: 5 Definitely Agree, 4 Tend to Agree, 3 Don't Apply or Unsure, 2 Tend to Disagree, 1 Definitely Disagree)
1.	I enjoy the course.
2.	I think this course has increased my literacy of sustainable design.
3.	I think the idea of sustainability is important to me as a designer.
4.	I will add sustainability to my future design work.
5.	This course helps me better cooperate and communicate with others.
6.	This course has developed my skills in transdisciplinary learning.
7.	I can understand the engineering concepts and methods involved in this course, such as sponge city construction.
8.	I think the teaching methods used in this course are reasonable.
9.	I think the design practice is challenging.
10.	Which part of the course do you like best?
11.	What are the difficulties encountered in this course?
12.	What are your comments and suggestions about this course?

3. Results and Discussion

3.1. Design Outcomes

Fuxi River is a tributary connecting the Qiantang River and Xiaoyang River that flows through several colleges and institutes. The sampling data showed high ammonia nitrogen concentrations and total phosphorus in the river water and fewer aquatic animals. The students conducted on-site inspections to understand the current situation of the river fully. The related reasons, including external pollution, internal pollution, hydrodynamic problems, and management issues, are shown in Table 2. The section in NingboTech

University is at the end of the river and adjacent to the student dormitory and canteens. It was determined that the pollution sources mainly include domestic sewage from upstream and polluted wastewater from non-point sources along the river. In addition, the slow flow of the river resulting in insufficient self-cleaning capacity is also a primary cause. The students found many hard revetments on both sides of the river, and in some areas the sparse vegetation leads to a poor landscape.

Table 2. The possible problems found by students and their corresponding treatment methods.

Possible Problems	Number of Groups with This Finding	Corresponding Treatment Methods
Upstream pollution	8	Blocking-up
Pollution from rain pipe	5	Rainwater seepage well
Runoff pollution	9	Permeable pavement, green roof, ecological revetment, etc.
Pollution released from sediments	7	Dredging, aquatic plant cultivation, the addition of chemicals
Atmospheric sedimentation	2	/
Sewage pipeline leakage	6	Reinforcement management and maintenance
Slow flow	10	Control of hydraulics, aeration
Simple ecological community	4	Add aquatic plants, animals, and microorganisms
Poor landscape	5	Landscape design

The design of the project is open-ended in theme. It requires students to analyze the problems through systematic and holistic thinking, choose targeted treatment measures, and consider the needs of the humanistic landscape of the campus. Initially, students were limited to in situ ecological treatment and landscape design. After discussing with the teacher, the scope was gradually expanded to the design of rainwater purification, such as green roofs and permeable pavements. Based on the survey results and analysis, each group formed its design scheme, and the results are shown in Figure 2. In a previous river treatment project, the Fuxi River was blocked up from the upper stream and purified by a biofilm-based bypass treatment device. All groups adopted the original measures; therefore, they are not shown in Figure 2. For example, the second group determined the design idea of "improving ecological elements so that ecological rivers have better self-regulation and self-repair capabilities". As shown in Figure 3, the self-purification capacity of the water body is comprehensively improved through aeration, microbial addition, and aquatic animal and plant cultivation. Furthermore, the LID facilities along the coast and sediment dredging ensure the reduction of pollutants entering the river.

After the scheme was formed, due to limited time, the students only carried out the detailed design of one or two nodes. In response to the problem of water accumulation on the riverside road, another group chose to renovate the original green belt along the river and introduced the accumulated water into the green space below the road through the gapped curbs and gravel belt (Figure 4). Rainwater would be stored and purified by the filtration of plants, soil, and microorganisms collected through drains, and then be discharged into the river. At the same time, a seat around the tree pool was designed to increase rest functions and the richness of the vertical space.

Some groups paid more attention to the improvement of the river landscape. For example, at the site of the original bypass treatment facility (Figure 5a), the students attempted to intervene in the "soft" and vital landscape to resolve the "contradictions" between the "hard" facility and nature. Figure 5b–e display a transformation of this open space into a sunken square to form a stepped, theater-like space for rest and activities. The use of lights and free curve polylines improved this space and its interest. Gravel pavement and permeable pavement were also used in this project to increase aesthetics and water permeability.

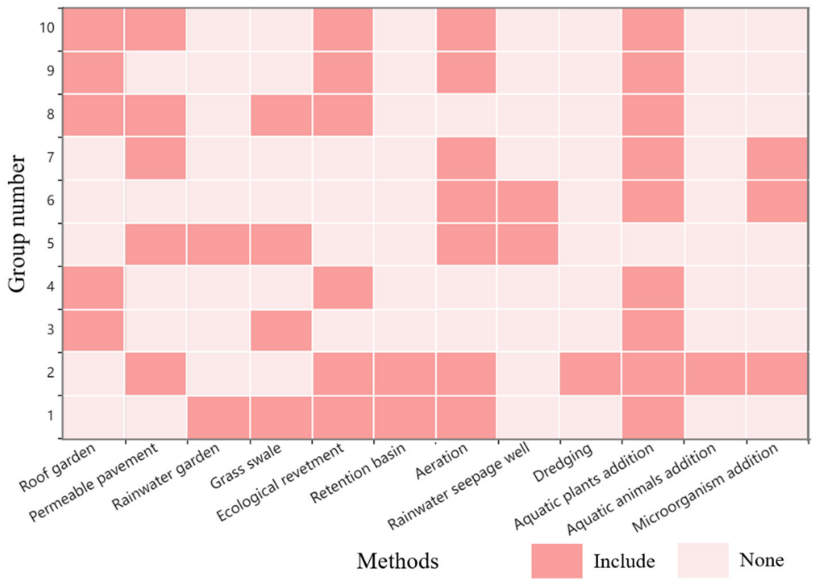

Figure 2. The design schemes of different groups for the Fuxi River Ecological restoration.

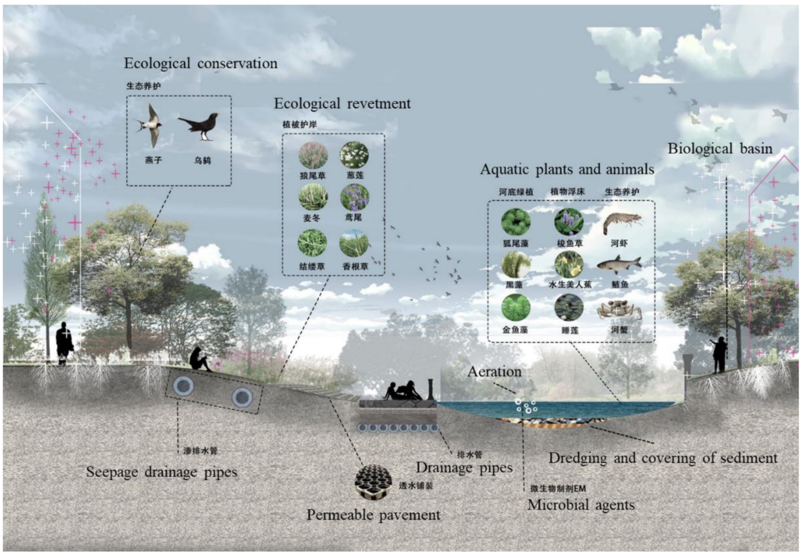

Figure 3. The ecological design scheme diagram of the second group (drawn by Dongge Wu and Yi Chen).

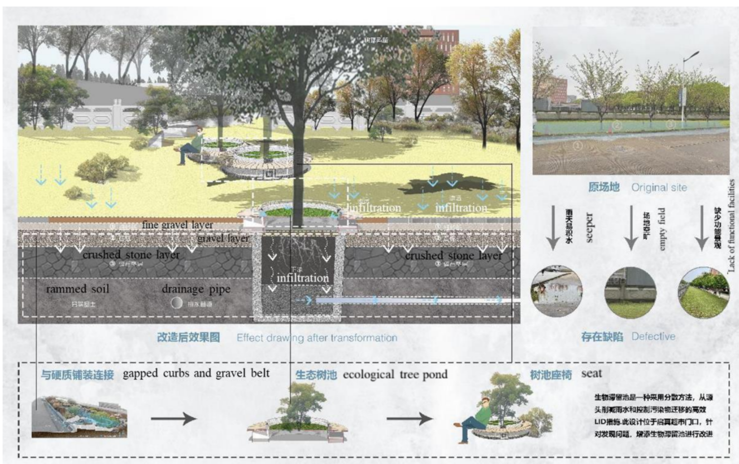

Figure 4. Before and after site renovation of Ecological pond (drawn by Shuyan Wu and Siqi Dai).

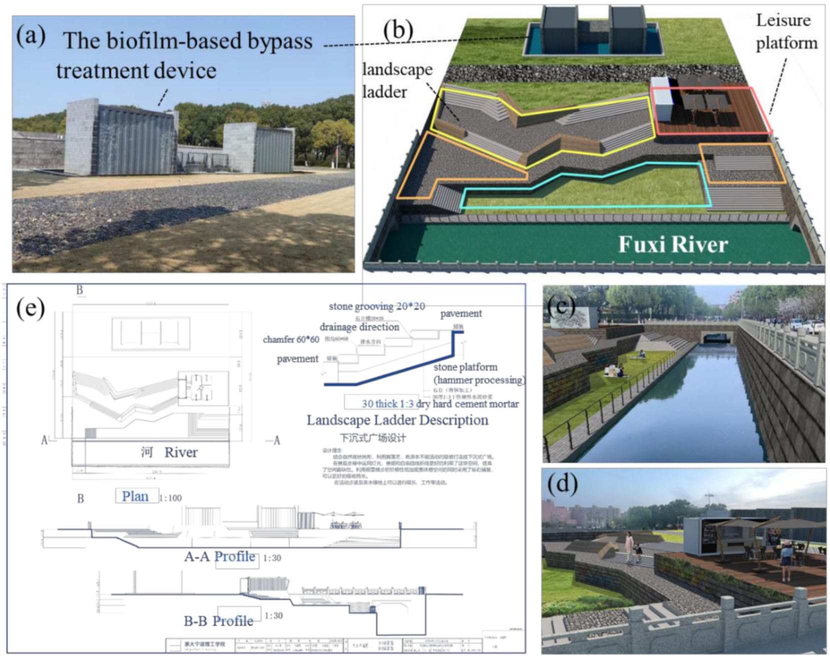

Figure 5. Square landscape design, (**a**) original site photo; (**b**–**d**) the rendering effect after the transformation, and (**e**) The CAD drawings (drawn by Shuman Wu, Tianwei Zhang, and Zixuan Wang).

3.2. Course Evaluation

3.2.1. Overall Evaluation of the Course

The results of the survey show that the response to the course was highly positive: the average score for enjoying the course (Q1) reached 4.73, of which 16 and 6 people chose the option of "Absolutely agree" and "Tend to agree", respectively. When answering which part of the course they liked the most (Q10), 11 students mentioned "outdoor visits". One student responded that their favorite part was "learning theory through outdoor surveys, then applying them to practical design". Three students mentioned "the integration of technology and design" and "urban planning from an ecological perspective". Two students pointed out the "communication and display of design results". These responses reflect a positive experience and the highlights of this course.

3.2.2. Achievement of Course Objectives

According to the statistical results, the achievement of the course objectives was also evaluated and analyzed. The correspondence between the questionnaire questions and the course objectives is listed in Table 3. It can be seen that the average score from Q2–Q7 relating to the course objectives is 4.74, indicating that the goal of this course is well completed. Up to 90.9% of the participants strongly agree that sustainable ideas are fundamental to designers, 72.7% believe that this course has deepened their understanding and awareness of sustainable design, and 81.8% of the students will add sustainability ideas to future designs. Regarding specific abilities, 72.7% of the students think they could understand some engineering concepts and methods, such as a sponge city, 68.2% replied that this course had improved their interdisciplinary learning ability, and 63.4% stated that the course helps to better communicate and collaborate with others. These results closely matched the course objectives, indicating that they increased students' knowledge of eco-environmental engineering and sustainability and their ability to solve complex problems in the future.

Table 3. Scores on questions related to course objectives.

Questions	Score	Average Score
Q2. I think this course has increased my literacy of sustainable design.	4.73	
Q3. I think the idea of sustainability is important to me as a designer.	4.91	
Q4. I will add sustainability to my future design work.	4.82	
Q5. This course helps me better cooperate and communicate with others.	4.59	4.74
Q6. This course has developed my skills in transdisciplinary learning.	4.64	
Q7. I can understand the engineering concepts and methods involved in this course, such as sponge city construction.	4.73	

3.2.3. Other Feedback

The average scores for "reasonable teaching methods" and "challenging curriculum design" were 4.77 and 4.59, respectively, suggesting that the course was relatively well organized. However, the students also encountered some difficulties in the learning process, and the most mentioned are calculation problems and the understanding of professional knowledge. Due to a lack of engineering experience, students were confused about the choice of method and materials. For example, when carrying out an aeration design, some students chose the tubular aerator commonly used in sewage treatment, though it is unsuitable for river restoration. Two students stated that having their CAD drawings meet the standard requirements was challenging because they had not undergone professional training. One student suggested the course could add more time for students' self-discovery. These questions and suggestions will contribute to the continuous improvement of the curriculum.

3.3. Experience and Lessons Learned

The outdoor tour was not only a favorite teaching method for students but also provided an easier understanding of the engineering contents. During their visit to the wetland park, students were introduced by the engineer to various methods used in the real-world restoration project, especially the selection of local pollution-resistant plants, which was extensively and rationally applied in their subsequent group design. In other reported cases, outdoor education [31] and field-based learning [32] have also received positive student responses. Outdoor education was considered a "good practice" if well-organized [33]. Das [34] proposes that properly organized and well-articulated academic field trips can provide students with learning experiences, comparative knowledge, critical understanding, and skills necessary to understand the world. The course only provided four lessons for outdoor visits using a traditionally structured and guided form. Due to the COVID-19 pandemic, student-led fieldwork with much-needed autonomy and flexibility [34], including the individual investigation of ecological restoration and landscape planning in Yuanshi Park, had been canceled. In the following courses, if possible, more forms and sites of outdoor activities will be provided to enhance the learning experience and effectiveness for the students.

Students in China who specialize in design often have a weaker math foundation, making them perform poorly at facility calculations and CAD drawings. Even if it is a simple problem for engineering students, it will bring certain difficulties for some design students. For instance, the area of the constructed wetlands can be easily calculated according to the selected organic surface loading and the pollutant removal amount. Still, many students make mistakes in the conversion of units. The focus of this course is to give students an increased understanding of the concepts and methods of sustainable engineering, so the emphasis on specific mathematical or engineering skills could be weakened. Of course, this is not to say that this part should be omitted entirely. A more acceptable method can be taken to convey it. There are several sponge city auxiliary software and cloud calculators. All control indicators can be easily obtained by inputting site data, and calculation tables and texts can be automatically output as required. These applications are beneficial for simplifying the difficulty of calculations.

Transdisciplinary learning has been viewed as the conclusive factor in changing the knowledge paradigm, offering a sustainable solution to meet the requirements for a diversity of knowledge needed today [35,36]. Usually, transdisciplinarity is a vague concept involving a wide range of subjects. A definition of transdisciplinarity given by Lang [37] states that it is a "reflexive, integrative, method-driven scientific principle aiming at the solution or transition of societal problems and concurrently of related scientific problems by differentiating and integrating knowledge from various scientific and societal bodies of knowledge". For young students, transdisciplinary learning offers a study methodology that could enable them to "understand a broad range of disciplinary approaches, to ask creative questions, to answer those questions with diverse tools" [38], and, finally, enhance their "complex problems-solving" and collaboration abilities that society needs. Lavrinoviča [39] summarized the four collaboration forms of transdisciplinary learning: (1) among learners, (2) between learners and teachers, (3) between learners and other external stakeholder groups of the learning process, and (4) among teachers. This course only takes the second form of transdisciplinary learning. However, in the questionnaire, the question regarding the improvement of communication and cooperation ability (Q5) received the lowest score, which can be attributed to the singleness of the students' majors in the group. Riedy [40] believes co-learning is crucial in transdisciplinarity research. In the collaboration among learners, students are encouraged to form collaborative teams with diverse backgrounds, which can bring new insights and knowledge through participative and even intercultural learning experiences. There is also a trend in engineering education to set courses involving different students from technical to social disciplines. The Tokyo Institute of Technology (Tokyo Tech) has a Department of Transdisciplinary Science and Engineering in the School of Environment and Society, where students can obtain academic knowledge and other abilities for solving complex problems [41]. Judge [42] presented a project-based course that bridges the gap between research and practice on the social science and engineering of resilient infrastructure for coastal adaptation. Therefore, a course for environmental design and municipal and environmental engineering could be established to improve the teaching outcomes further.

It should be pointed out that the above discussion is mainly based on the students' design outcomes and perceptions, which affects the evaluation and development of the course to a certain extent, since students will not be at a stage in their careers where they understand which skills and knowledge they will need in their future work, and they will be working at a time when societal and environmental conditions will have changed. The evaluation by external tutors or external stakeholders and interviews and surveys among various categories of professionals will be included in future work to make students actually achieve learning outcomes and progress in the skills that the course was intended to develop.

4. Conclusions

The current sustainable development goals put forward new requirements for higher education. The course "Environmental Engineering and Technology" at NingboTech University provides transdisciplinary learning practice for the environmental design students by integrating eco-environment engineering and landscape design with various methods. Through the presentation of the Fixi River ecological restoration project and the questionnaire survey, it was determined that the students who were very active in participating in the course achieved growth in sustainability literacy. The results also confirm the importance of outdoor education and project-based teaching. Additionally, the lowering of the requirement for mathematical skills through the internet tools usage and the formation of multidisciplinary team learning is expected to improve future teaching outcomes further. These courses must be coordinated at multiple levels so the trained talents can comprehensively solve complex problems for sustainable development.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su141912379/s1, Text S1: The English version of the questionnaire.

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