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Engineering Education for Sustainable Development in China: Perceptions Bias between Experienced Engineers and Engineering Students

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***Abstract*—**Nowadays sustainable development has increasingly become an important research topic of engineering education all over the world. Engineering Education for Sustainable Development (EESD) highlighted the importance of addressing sustainable development in engineering practice. However, whether and how the professional engineering learning and experience affect those perceptions is an interesting research topic especially in Chinese context. Our study fills this gap by investigating perceptions bias of EESD among first-grade engineering students, fourth-grade engineering students and experienced engineers using a triple-dimensional model. Our goal is to find the effect of engineering learning and experience on sustainable development and make these learning and experiences more accessible for students and engineers in school and workplace context. The data (n = 138) came from a Likert questionnaire based on the triple-dimensional model of EESD adopted from literature reviews and the data contain 48 first-grade students, 56 fourth-grade students and 34 engineers with rich working experience from Environmental Engineering, Energy Engineering, Chemical Engineering and Civil Engineering in or graduated from Zhejiang University, China. One-way ANOVA analysis was used to find the difference in different dimensions among the three groups. The statistical results show that both engineering students and engineers have a well understanding of sustainable development in ecology dimension of EESD while there are significant differences among three groups as to the socio-economy and value rationality dimensions of EESD. The findings provide empirical evidence that both engineering learning and professional engineering experience are helpful to cultivate the cognition and perception of sustainable development in engineering education. The results of this work indicate that more practical content should be added to students' engineering education while more theoretical content should be added to engineers' training in order to promote the engineering students' and engineers' perceptions of sustainable development. In addition, as to the design of engineering courses and professional practice system for sustainable development, we should not only pay attention to the ecological aspects, but also emphasize the coordination of ecological, socio-economic and human-centered sustainable development (e.g., engineer's ethical responsibility).

***Keywords*—**Engineering education, sustainable development, experienced engineers, engineering students.

I. Introduction

AS an important tool of human exploring and transforming the world, engineering is regarded as a significant means to protect the ecological environment as well as improve the quality of human daily life especially in an era when the world facing Grand Challenges [1] such as depletion of natural resources and the outbreak of COVID-19. Sustainable Development (SD) is an eternal theme of mankind, which is related to the future development of the world. Throughout human history, it is obvious that engineering has driven the advance of civilization while engineering education has taken the responsibility of cultivating and training enough experienced engineers to advance the human progress, thus engineering and engineering education should be regarded as an extremely important part of SD. For example, the World Federation of Engineering Organizations (WFEO) pointed that engineering education could play a considerable role in SD in the report *A Plan to advance the achievement of the UN Sustainable Development Goals through engineering* [2] in October 2018. The 40th General Conference of UNESCO in November 2019 adopted a resolution declaring that March 4 will be set as the *world engineering day for sustainable development* every year [3], to give prominence to the contribution of engineers and engineering technologies for SD, and to enhance public awareness of the important role of engineering technology in achieve the goal human life. And the World Engineering Day 2021, with the theme of "*Engineering for A Healthy Planet-Celebrating the UNESCO Engineering Report*", focused on celebrating the launch of the 2nd UNESCO Engineering Report "*Engineering for Sustainable Development: Delivering on the SDGs*" [4]. In the future, more reliable actions need to be taken to promote the integration of SD and engineering education practice to help more engineers and engineering students as well as common people change the way of thinking and working in some ways, and ultimately achieving SD goals.

Building on the body of literature, our research work focuses on and answers the question that whether and how professional engineering learning and practicing experience affect the engineers' and engineering students' perceptions of engineering education for sustainable development (EESD) in the Chinese context. We hypothesize that real engineering practicing experience like designing a hydropower project or building an urban park will be beneficial for the perceptions of EESD in all dimensions. In the following sections, we first review the concepts and different dimensions of EESD in great detail and try to make a clear definition for every dimension. Then, we will explain how to design a survey to collect some data from experienced engineers and engineering students by a

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questionnaire at Zhejiang University, China. Next, we use one-way ANOVA method to analyze the data and explain the analysis results. Finally, we give our findings and suggestions based on the analysis results. We hope to bring some inspiration on the field of EESD through this exploratory study.

II. Literature Reviews

Prior research has provided detailed descriptions of this theme through case studies or theoretical research. In this part, we first review the evolutionary process of the concept of EESD. Then we review some academic articles and public reports about the EESD and establish a preliminary conceptual framework about EESD, which included environmental dimension, socio-economic dimension, and human-centered dimension.

A. The Concept of EESD

In 1987, the World Commission on Environment and Development (WCED) issued an important report named *Our Common Future*, which pointed out that SD is a way of development that can meet the needs of the present without compromising the ability of future generations to meet their own needs [5]. In 1996, American Society of Civil Engineers (ASCE) proposed an abbreviated definition that EESD means the effective use of environmental and natural resources in engineering practice [6]. Afterwards, EESD has received more and more attention in the study of engineering education. For example, some scholars hold the belief that EESD not only includes environmental protection and effective utilization of natural resources, but should also refer to the economic and social aspects [7]. Besides, some scholars put forward that EESD should include the human value contents such as engineer's morality and professional ethics [8]. The UN and the WFEO have discussed the connotation of EESD for many times, and released a series of research reports on this topic such as "*Project 2030 Plan*" [9], emphasized the important value of EESD.

Based on the representative definitions and points (Table I), we conceptualize EESD to be a mode of engineering education that uses eco-friendly scientific knowledge and engineering technology to promote the coordinated development of the environment, economy and society, as well as to cultivate engineers' sense of social responsibility. There are three key points: a) EESD is an engineering education model based on an environmentally friendly culture. b) It not only pays attention to the ecological environment, but also advocates promoting economic prosperity and social inclusion in some way. c) Engineers and engineering students are important parts of EESD because the thinking and behaviors of them can make a huge influence on the future of EESD.

B. Three-Dimensions of EESD

The existing literature on EESD was mainly about three themes: environmental protection or natural resources cancellation, economic development or inclusion of the society, and human-centered engineers' cultivation. The three themes co-exist in prior research but have different emphasis on dimensions of EESD.

TABLE I
Key Points of the Concept of EESD from Public Articles and Reports

Institution	Time	View	Points
ASE	2002	Engineers and scientists should work together to adapt to existing technologies, create new technologies, meet social needs, improve resource utilization, and minimize waste generation [6]	resource utilization
EPA	2007	Design and use economically feasible processes and products to reduce the generation of pollution sources and minimize the risk to human health and the environment [7]	Environment protection
WFEO	2018	SD engineering education is a comprehensive and systematic concept, which should combine the progress of economic development, social inclusion and environmental sustainability [8]	economic prosperity Social Inclusion Environmental sustainability
WFEO	2018	Young engineers are very important to the process of SD. They are not only stakeholders to achieve SD goals, but also key actors to promote SD goals [9]	The role of engineers

1) Environmental Dimension

Ecological and environmental protection is an important theme of EESD, which is also the aspect that engineering education should pay attention to. After the industrial revolution, engineering education and engineer training are carried out by the principle of economic rationality mainly. Engineering education's goal is to tell the students how to seek and implement proper technology to solve complicated or complex engineering problems, while they usually ignore the environmental or moral problems in the process of using engineering technology [14], which has caused a series of severe ecological problems, such as environmental pollution and waste of resources [15]. Facing challenges, engineering education began to change and develop a new educational model to support SD especially deal with severe ecological problems, as a result, a lot of concepts like 'green engineering' and 'green engineering design' appear one after another in the professional engineering practice.

In 2003, researchers like Anastas and Zimmerman proposed 12 principles of Green Engineering, initially established a clear framework for engineering products, processes and design which can meet the standards of ecological and environmentally SD [16]. The 2004 International Conference on Engineering Education for Sustainable Development (ICEESD) in Barcelona proposed that ecological sustainability should be included as critical literacy in the engineering education guidance documents of all countries so that the ecological environment should become an indispensable part of the concept of EESD and the practice of engineering talents training [17]. It meant that the integration of ecological and environmental concepts in engineering education has become the general trend all over the world. Late in 2007, the EPA and AIChE first proposed the whole concept of green engineering which emphasizes integrating the attitude, value and principles with environmental awareness into engineering design, aiming to improve the local and global environmental quality [18].

TABLE II
12 PRINCIPLES OF GREEN ENGINEERING [18]

Principle	Contents
1	Designers need to strive to ensure that all material and energy inputs and outputs are as inherently nonhazardous as possible.
2	It is better to prevent waste than to treat or clean up waste after it is formed.
3	Separation and purification operations should be designed to minimize energy consumption and materials use.
4	Products, processes, and systems should be designed to maximize mass, energy, space, and time efficiency.
5	Products, processes, and systems should be "output pulled" rather than "input pushed" through the use of energy and materials.
6	Embedded entropy and complexity must be viewed as an investment when making design choices on recycle, reuse, or beneficial disposition
7	Targeted durability, not immortality, should be a design goal.
8	Design for unnecessary capacity or capability (e.g., "one size fits all") solutions should be considered a design flaw.
9	Material diversity in multicomponent products should be minimized to promote disassembly and value retention.
10	Design of products, processes, and systems must include integration and interconnectivity with available energy and materials flows.
11	Products, processes, and systems should be designed for performance in a commercial "afterlife".
12	Material and energy inputs should be renewable rather than depleting.

2) Socio-Economic Dimension

The ecological environment is the core direction of EESD. But there is a huge difference between regarding SD as an environmental problem or regarding it as a multidimensional challenge involving the economy, environment and society. It is of great value to develop EESD in multi-dimensions including economy and society to solve the real social development problems. The socio-economic dimension of EESD contains a lot of important themes of engineering education like social equity, poverty alleviation, gender equality and social inclusion, etc., which are really important aspect related to the development of the world.

Mihelcic and Hokanson proposed a three-factor model for SD of science and engineering in 2005 [19]. The model shows that SD is a triangular framework composed of economic/ industrial sustainability, environmental sustainability and social sustainability. Besides the ecological environment, this model brings the economic and social factors into the concept of SD, forming a multi-dimensional conceptual framework. The new concept of EESD makes up for the deficiency of ecology-oriented concept and promotes the continuous evolution of engineering education practice in the path of social development elements coordination.

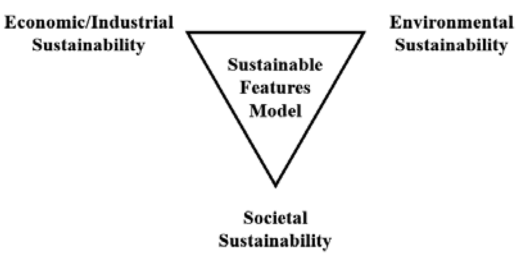

Fig. 1 Triple-dimensional model of SD

3) Human-Centered Dimension

Engineers, as engineering problem-solver and decision-makers, are the most important part of EESD. In the past, when it comes to SD, people's first reaction is related to the themes about the ecological environment. It seems that engineering education has the responsibility to teach people how to do the right things instead of how to do things rightly. As a result, engineers are more and more like some technical machines without any feelings and emotions, who are working day by day but do not know their important value at all. To have a sustainable future, we need to call for an engineering education mode that attaches importance to the value rationality of engineers. And we need the ethical and moral engineering 'managers' who will make the right decisions.

In the article *engineering education and sustainable development: the missing link* [20], Alrawahy deeply discusses the value rationality and technical rationality of engineering education. He thought that 'Literature and debate on SD have concentrated mainly on physical and tangible issues and assets: population growth, resource depletion, environmental impact, climate change, poverty, and illiteracy. While the list is not exhaustive, many pundits have failed to realize that the most pressing ingredient and the scarcest resource facing the sustainability concept is not in the physical components of society's endowment, but rather, the ethical and moral values of 'managers' – individuals that are entrusted to plan, oversee, and implement a successful economic and social development program' [20]. We hold the belief that caring for engineers' individual value and personal development are also important issues of EESD. And paying attention to the important contribution of engineers' individual value has gradually deepened the research focus of EESD from environmental, economic, social and other technical rationality levels to engineers' individual value rationality level.

TABLE III
THE DIMENSIONS OF SD

Dimensions	I	II	III
Features	environmental protection	economy and society	human-centered rationality
Core content	EESD take the environmental protection and resource saving seriously	economic development, social inclusion and environmental are three pillars of EESD	engineering ethics and social responsibility of engineers should be included in the construct of EESD
Themes	green engineering, resource depletion, pollution prevention, climate change, climate warming, etc.	economic prosperity, society inclusion, eliminate poverty, gender equality, etc.	engineering ethics, social responsibility, moral restraint, multi-cooperation, etc.

III. METHOD

A. Participants

The data we used in this study came from a survey carried out in Zhejiang University (ZJU) during fall 2020 which is a famous research-focused university with excellent engineering education in China. The survey examined how engineering students (N = 408, including 48 first-grade and 56 fourth-grade) studying in school and experienced engineers (N = 34) who have graduated from ZJU as well as participated in some real engineering projects think about EESD with dimensions mentioned in the part of the literature review. Table IV describes participants' self-identified gender in our sampling population. We can find those male participants were significantly more than female participants (23% vs. 66%) since there are more male engineering students and experienced engineers than female in China.

TABLE IV
PARTICIPANTS' REPORTED GENDER

Groups	Gender			
	Female	Male	Not report	Total
First-grade students	9	35	4	48
Fourth-grade students	11	38	7	56
Experienced engineers	12	18	4	34
Total	32(23%)	91(66%)	15(11%)	138

The majors of professions of surveyed engineering students and experienced engineers were distributed in Environmental Engineering, Energy Engineering, Chemical Engineering and Civil Engineering and the percentages of the four majors or professions in every group are shown in Fig. 2. We chose these four majors or professions as our sampling range because we found they are closely related to SD. We tried to keep a balance in the number of sampling we surveyed among each majors or professions, but there are still some significant differences especially in the group of experienced engineers.

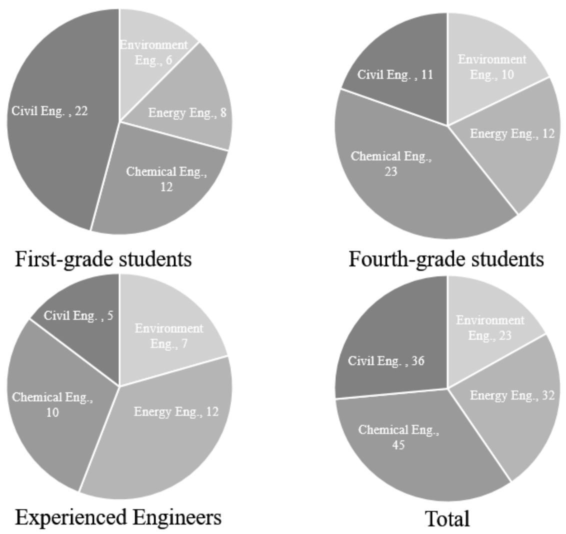

Fig. 2 Participants' Majors

B. Survey Context

ZJU carries on the specialty-free recruitment for first-grade undergraduate students. We surveyed the first-grade engineering students as they just finished the College Entrance Examination and would attend their professional studies soon. Most of them are very interested in the engineering professions and have learned some basic engineering knowledge like mechanical knowledge, physics, chemistry during their high school time, etc. However, most of them did not have the experience of real engineering projects and did not know how engineering works. Thus, all their perceptions about EESD came from their preliminary understanding of engineering. We surveyed fourth-grade engineering students as most of them have learned some professional engineering courses including some relating to SD very closely like environmental ecology. What's more, there are few of fourth-grade students have participated in the real engineering practice projects. So, we made the hypothesis that the perceptions of EESD for fourth-grade engineering students are mainly from curriculum learning rather than practical engineering activities. In the last, we surveyed experienced engineers who have graduated from ZJU as they received almost a similar engineering education during university while most of them have participated in real engineering projects such as designing and building some architectures. So, we hypothesize that the perceptions of EESD for experienced engineers came from both the theoretical study and practical experience. We hold the preliminary belief that experienced engineers have a more comprehensive and deeper understanding of EESD in each dimension considering their rich professional knowledge and experience.

C. Questionnaire

TABLE V
ITEMS OF THE TEST SCALE

Dimensions of EESD	Items	Description
Environmental	1	Whether the construction of project will cause serious pollution to the local environment?
	2	Whether the construction of project will cause the waste of natural resources?
	3	Whether the construction of project will destruct the ecology biodiversity?
Socio-economic	4	Whether the construction of project will promote the local economic development effectively?
	5	Whether the construction of project will eliminate poverty and promote social inclusion?
	6	Whether the construction of project will be beneficial to achieve social equity?
Human-centered	7	Whether the persons participating in the engineering project have a high sense of social responsibility?
	8	Whether the persons participating in the engineering project have moral character?
	9	Whether the persons participating in the engineering project have teamwork ability?
Hypothetical Situation	If you are an engineer, now you are being in charge of site selection and leading the design and manufacture of a large hydropower station project in Western China. Will you consider the following issues in the process of engineering design and implementation?	

Based on the existing research, we designed a Likert Scale questionnaire with three dimensions of EESD which consisted of different attitudinal scales to answer the questions related to SD (e.g., "1-Strongly Disagree" to "5-Strongly Agree"). And the questionnaire was administered in an online format with Wenjuanxing (https://www.wjx.cn) and took approximately 15 minutes to complete. Besides, the questionnaire consisted of a hypothetical engineering situation before the scale questions like "Suppose that you are an engineer, now you are being in charge of the site selection and leading the design and manufacture of a large hydropower station project in Western China. Will you consider the following issues during the process of engineering design and implementation?" By this way, we expect that the respondents can consider the issues related to SD during the process of design and implement a real engineering project. We also collected some demographic information like gender, educational level, professions, etc., about the participants after the scale questions part. And at the end of the questionnaire, we made an open-ended question which mainly collected the reasons why the participants select a low or high score in a specific item.

D. One-way ANOVA Analysis

One-way ANOVA analysis is suitable for the comparison of means between two or more groups and its null hypothesis is that there is no difference between the means of multiple groups. For ANOVA analysis, some pre-conditions need to be satisfied: a. There is a categorical independent variable as well as a continuous dependent variable. b. The data in each group obey the normal distribution. c. The data of each group meet the homogeneity of variance. d. The sample size ratio between groups should not exceed 1:4 [21]. We first use Shapro-Wilk (S-W) method to test if the data from three groups correspond to normal distribution. The results show that the groups of socio-economic dimensions of EESD ($p = 0.062$) and human-centered dimension of EESD ($p = 0.327$) can meet the normal distribution requirement, but the data of the environmental dimension of EESD ($p = 0.000$) group failed to pass the test. Then we tested Skewness and Kurtosis for every group and the results show that all three-group data can be approximately considered to obey the normal distribution. The Q-Q plot made by SPSS software gives us familiar information.

TABLE VI
TEST RESULTS OF NORMAL DISTRIBUTION

	environmental	socio-economic	human-centered
S-W test	$p = 0.000 < 0.05$	$p = 0.062 > 0.05$	$p = 0.327 > 0.05$
Skewness	-0.970	0.0334	-0.169
Kurtosis	0.627	-0.727	-0.079

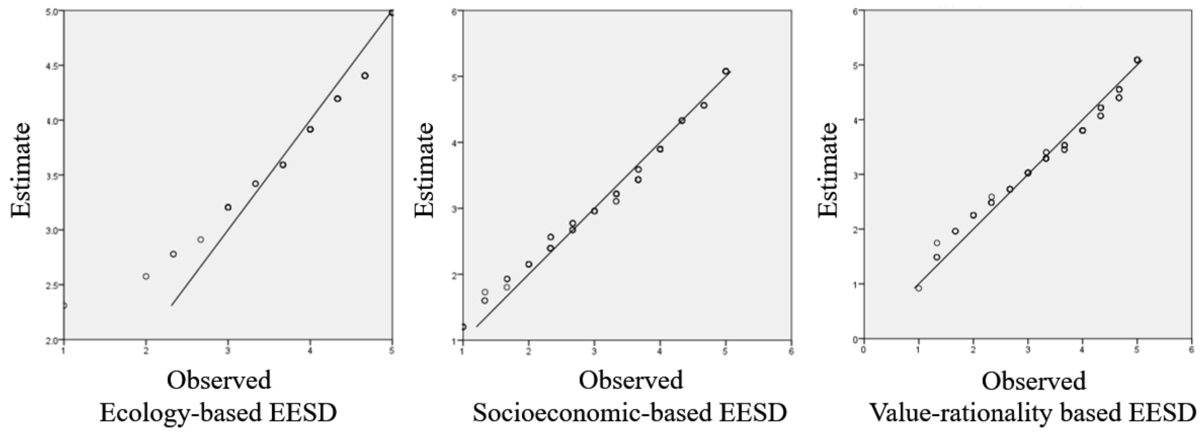

Fig. 3 Q-Q plots for three Dimensions of EESD

IV. RESULTS

A. Descriptive Analysis

The descriptive statistical results show that all three groups have the remarkable perception of SD concept in the environmental dimension while there is little difference between the perception of socio-economic and human-centered dimensions of EESD, lower than environmental dimension. The results show that both engineering students and experienced engineers are more familiar with the concept of EESD in an environmental dimension like ecological environment protection, resource conservation, biodiversity, etc., instead of the other two dimensions.

TABLE VII
DESCRIPTIVE STATISTICAL RESULTS

	N	Min	Max	Mean	S.E	S.D
environmental	138	1.00	5.00	4.33	0.07	0.77
socio-economic	138	1.00	5.00	3.50	0.09	1.06
human-centered	138	1.00	5.00	3.70	0.09	1.06
N	138					

B. Variance Analysis

1) Environmental EESD

One-way ANOVA analysis was used to test the perception of environmental dimension of EESD among first-grade engineering students, fourth-grade engineering students and experienced engineers. The data in each group met the normal distribution approximately and the homogeneity of variance ($F = 0.223$, $P = 0.801 > 0.05$). The results show that there is no significant difference for the perception of environmental dimension of EESD among different groups ($F = 0.204$, $P = 0.816 > 0.1$), which indicates that ecological environmental protection within EESD has become a common understanding among engineering students and engineers at all stages.

2) Socio-Economic EESD

Based on different identities (first-grade engineering students, fourth-grade engineering students and experienced engineers), the socio-economic dimension of EESD was analyzed by One-way ANOVA analysis. The data met the normal distribution in each group, but the variance was not homogeneous ($F = 4.661$, $P = 0.011 < 0.05$). Therefore, Welch test was used to determine whether there was any difference between the groups. Because of the lack of homogeneity of variance, Game Howell method was used to conduct the back test.

The results showed that Welch $F(df_1, df_2) = 37.745(2,76.792)$, $P < 0.001$, indicating that different groups have significant differences for the perception of socio-economic dimensions of EESD. The results of Game Howell analysis showed that the scores of fourth-grade engineering students in the perception of socio-economic dimensions of EESD are significantly higher than those groups of first-grade engineering students and experienced engineering students, which was contrary to our hypothesis in some way.

3) Human-Centered EESD

One-way ANOVA has been used to test the perception of three groups on the human-centered dimension of EESD. The data in each group met the normal distribution and the homogeneity of variance ($F = 0.013$, $P = 0.987 > 0.05$). Thus, a Tukey's HSD method was used for back test. The test results showed that there are significant differences among the three groups for the perception of the human-centered dimension of EESD, and the experienced engineers have the highest score, followed by the fourth-grade engineering students, while the first-grade engineering students have the lowest score, with an average score of 2.72.

TABLE VIII
RESULTS OF ONE-WAY ANOVA ANALYSIS

Dependent	Groups	N	M(±SD)	F	p	Back Test(p)	
						1	2
Environmental	1.	48	4.27 (± 0.73)	0.204	0.816		
	2.	56	4.36 (± 0.76)				
	3.	34	4.35 (± 0.88)				
	Total	138	4.33 (± 0.77)				
Socio-Economic	1.	48	2.90 (± 1.01)	4.661	0.011		
	2.	56	4.24 (± 0.72)			0.000	
	3.	34	3.12 (± 0.89)			0.483	0.000
	Total	138	3.50 (± 1.06)				
Human-Centered	1.	48	2.72 (± 0.75)				
	2.	56	4.09 (± 0.82)	58.70	0.000	0.000	
	3.	34	4.42 (± 0.78)			0.000	0.000
	Total	138	3.70 (± 1.06)				

Note: 1 = Group1-First-grade engineering students, 2 = Group2-Fourth-year engineering students, 3 = Group3-Experienced engineers

V. FINDINGS AND DISCUSSION

Through the survey conducted in ZJU about the perception of EESD among first-grade engineering students, fourth-grade engineering students and experienced engineers who have graduated from the same university, we can report some interesting and meaningful findings:

(1). Within the three dimensions of EESD, all three groups (first-grade engineering students, fourth-grade engineering students, and experienced engineers) have better perceptions about environmental dimension than the other two dimensions, which shows that both engineering students and experienced engineers can well understand the significant importance of ecological and environmental protection such as resource conservation and biodiversity in their engineering study and work. It further reveals that the engineering education consisting of the environmental protection in China has reached a very good level, owing to the environmental supervision implemented by government and the environmental assessment based on public policy.

(2). Most surprisingly, the fourth-grade engineering students group performed better with the perception of the socio-economic EESD concept than both the first-grade engineering students and experienced engineers' group, which is not in accord with our hypothesis. For first-grade engineering students, we think maybe that they lack the relevant knowledge and real practical experience of engineering work or SD, so their perception of EESD may stay at the ecological level only. However, we are very confused about why experienced engineers who have graduated from university 3 years ago or above should have a lower perception about EESD than fourth-grade engineering students studying in school considering their rich professional engineering experience. With the above question, we conducted a focusing interview with some engineers who have participated in the survey. Gradually, we got the following explanations: Firstly, with the rapid development of the economy and the gradual improvement of the governance system, the competition in the field of engineering is becoming more and more fierce, as well as the marginal profit of most engineering projects is declining year by year in China. So, it is more and more difficult to get proper engineering projects, therefore, experienced engineers will pay more attention to the cost, feasibility and other issues in the process of designing an engineering project, and ignore the impact of the engineering projects on the local economic development and social inclusion, which they think is "leader's" responsibility. Secondly, under the increasingly environmental policy constraints, engineers are required to consider the environmental issues more than social and developmental problems during the process of a certain engineering project. As a result, from an engineer's point of view, SD is totally equal to ecological protection.

(3). With a deeper understanding, engineering students and experienced engineers pay more and more attention to the importance of human-centered dimension of EESD such as engineering ethics, moral responsibility, teamwork, etc. And the results of ANOVA analysis show that, to a certain extent, engineering curriculum learning and engineering practice experience can both deepen the perception of human-centered dimension of SD, which explains why the first-grade engineering students who lack practical training have a limited perception of this dimension of EESD.

VI. SUGGESTIONS

Engineering plays a key role in SD like promoting poverty eradication, addressing climate change, disaster reduction and prevention and other important issues. As an important activity to foster qualified engineers, engineering education is of great significance to the SD of the world. The results above give us some enlightenment and the following measures should be paid attention to: Firstly, both engineering courses and professional practice are beneficial to improve the perceptions of EESD, so in the future, we should take some effective measures to integrate the concepts of SD into the engineering curriculums and practice system which can help engineering students and engineers know SD beyond a single perspective. Then we should promote the interdisciplines actively, especially the interdisciplinary of engineering with economic, social, and humanities disciplines, and guide students to pay attention to the social value of engineering projects, which can improve the perceptions of the human-centered dimension of EESD. In particular, it is necessary to guide experienced engineers to pay attention to the role of the real engineering projects in social and economic development, such as social inclusion, gender equality, etc., The engineering ethics education system based on the Chinese situation should be improved gradually, which is one of the important measures to guide engineering students to deeply and comprehensively understand SD.

VII. Limitations and Future Work

We acknowledge some of the limitations of the results presented above. This study and findings were carried out with a small sample who were engineering students or experienced engineers from four professions in ZJU, thus the research conclusion cannot accurately reflect the whole China's situation and cannot be generalized to all engineering students or professional engineers. We selected our sample according to the principle of random sampling in four professions, but we only collected 138 samples, which is a very small proportion considering there are about 7 million engineering students in China. On the other hand, ZJU is one of the top comprehensive universities in the world, so it has the first level engineering students in China. However, there are many other engineering universities in China whose students' quality may not be as good as ZJU. These universities also play an important role in China's EESD. They have cultivated a large number of engineering talents and engineers in many fields. But in our research, we ignored these universities' critical role and the characteristics of their students.

What we are doing is an exploratory and general study. We made the hypothesis that engineering learning in class and professional engineering practice can both be beneficial to the perception of EESD. But our findings only reveal that experienced engineers can do better or worse in some dimensions of EESD. There may be various types of engineering courses and engineering practice experience that have affected the understanding of EESD, but we did not make a meticulous exploration. The effect size of various factors has not been tested either.

Finally, we only measure the individual perception of SD, but do not observe the real engineering practices following the requirements of SD. That's to say, the extent to which perception can be transformed into action did not get tested. In the survey, we found that a large number of engineering students or engineers have a complete and comprehensive perception of SD, but they do not follow the guidance of the principles of SD to carry out the real engineering design and construction in practice. As a result, the perception of sustainability does not work at all. Therefore, our future work on EESD should focus on the following points: Firstly, considering the extreme importance of engineering in promoting SD of the world, we should expand the sample size of the survey, including universities in different levels and students or engineers of different professions. Secondly, we need to design rigorous survey scales about EESD to test how specific factors like curriculum or practice influence the perceptions of EESD, making the causal link clearer. Finally, it is imperative to explore the specific path and influence mechanism of EESD perception to real engineering practice and how students and engineers utilize their perceptions of EESD to guide their engineering practice.

VIII. Conclusion

Nowadays because of some engineering challenges such as COVID-2019 epidemic outbreak, SD has increasingly become an important research topic of engineering education in the world. However, the research on EESD has not been very popular in China, and the concepts of SD are still confused especially in engineering field. It is no doubt that engineering is an important force to promote the SD of the world, so is the engineering education. In this study, we designed an exploratory research work and provided empirical evidence for the engineering students' and experiences engineers' perceptions of EESD.

According to the existing literature, we put forward a SD framework including ecology, socio-economy and value rationality, and designed a Likert-Scale questionnaire under the three-dimensional framework. Using the questionnaire, we surveyed 138 engineering students and engineering in ZJU from Environmental Engineering, Energy Engineering, Chemical Engineering and Civil Engineering. Then we use one-way ANOVA analysis to examine if there is significant difference for the perceptions of EESD among first-grade engineering students, fourth-grade engineering students and experienced engineers. The results indicate that both engineering students and engineers have a well understand of ecology dimension of EESD while there is significant difference among three groups as to the socio-economy and value rationality dimensions of EESD. Fourth-grade engineering students performed better than the other groups in socio-economy dimension, while experienced engineers performed better than engineering students in value rationality dimension. The findings provide empirical evidence that professional engineering learning within universities and professional engineering experience in real workplace are helpful to cultivate the cognition of SD.

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