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Original Research

Perceptions of Architecture Students on Energy-Saving and Emission Reduction in Green Building Design: A Case Study from a Chinese University

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Abstract

The architectural design and the policies of energy-saving and emission-reduction proposed by the state are mutually influenced. In this case, the architecture major in colleges and universities should pay more attention to the training of talents under the policy to meet society's need for talent. Universities are essential places for the personnel cultivation of architecture students, and it is necessary to understand the perceptions of such students about energy-saving and emission reduction in green building construction in China. Regarding their major (sophomore to graduate architecture students at Anhui Polytechnic University) and related courses about green buildings, this study assessed and compared students' opinions about the energy-saving and emission reduction of green buildings. To achieve the research goals, 140 questionnaires were conducted among the students as mentioned above. The study results showed that most respondents believed it is essential to promote energy-saving and emission reduction of green buildings in the context of high energy consumption in China's buildings. Students thought that building energy-saving design and technology, building materials courses, and experimental teaching methods were more important in student teaching. It was also clear from the research that students spend more time in the dormitory and library, thus the energy-saving and emission-reduction technologies can focus on these building types. Based on the Chi-square test, the influence of gender and grade on the results of some questions was further investigated.

Keywords: questionnaire, green building, energy-saving and emission-reduction, curriculum, chi-square test

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Introduction

The global mean surface temperature (GMST) in 2021 is 1.11ºC higher than the pre-industrial baseline, making 2021 a scarce hot year in global record [1]. Global warming will cause a global redistribution of precipitation, melting of glaciers and permafrost, and rising sea levels, which endanger the balance of natural ecosystems, affect human health, and even threaten human survival [2-4]. In the early years, while China's economy was increasing, resource wastage and environmental pollution also intensified, and the contradiction between development and environmental pollution became increasingly prominent [5-6]. The public strongly reflected on the environmental pollution problem [7]. Without adjusting the economic and industrial structure and further transforming the economic growth mode, energy, environment, and society will not be able to continue, and economic development will be challenging to move forward [8-9]. In 2006, the binding targets of reducing energy consumption per unit of GDP by 20% and reducing total emissions of major pollutants by 10% during the Eleventh Five-Year Plan were proposed at the conference of the Eleventh Five-Year Plan for National Economic and Social Development [10].

In China, building energy consumption accounts for more than 27% of the total energy consumption, and it is still increasing at 1 percentage point per year [11]. Statistics from the Ministry of Housing and Urban-Rural Development of the People's Republic of China show that nearly 2 billion square meters of new housing construction area are built in urban and rural areas in China, of which more than 80% are high-energy buildings [12]. Besides, nearly 40 billion square meters of existing buildings, more than 95% are high-energy buildings [13]. Against this background, the green building is introduced to achieve sustainable development in the construction industry [14-15]. Green building design refers to implementing the concept of green development by achieving the goal of energy-saving and emission reduction through spatial design, building functional design, indoor and outdoor physical environment design, and energy-saving design [16-17].

Building design should make reasonable use of existing resources, develop renewable resources, reduce the energy consumption of buildings, and achieve harmony between buildings and the environment so that buildings can play an excellent energy-saving effect in the use process [18-19]. At present, the global green building evaluation systems mainly include the China Green Building Evaluation Standard (GB50378-2014), the U.S. Green Building Evaluation System (LEED), the British Green Building Evaluation System (BREE-AM), the Japanese Comprehensive Environmental Performance Evaluation System for Buildings (CASBEE), and the French Green Building Evaluation System (HQE) [20-21].

The university's campus is a place for students' study and activities. When designing the campus building, it is not only necessary to consider the needs of students, but also to promote the cultural atmosphere of the university, and at the same time to follow the concept of green and energy-saving. Based on this, we investigated and analyzed 140 architecture students' knowledge and understanding of energy-saving and emission reduction of green buildings through a questionnaire, which mainly included two aspects of the curriculum related to green buildings and campus life. The main purpose of this study is to understand the students' cognition of energy conservation and emission reduction, based on which to promote the reform of relevant courses for our country and meet society's needs for talent education.

Research Method

Study Area

Anhui Polytechnic University (31.338822°N, 118.411518°E) is selected as the study area located in Wuhu City, Anhui Province, with a humid temperate subtropical climate with hot and muggy summers, and cold winters. The university has more than 20,000 undergraduates, more than 2,100 graduate students and 1,800 faculty. The university was built in 1986, with a total area of 720,000 square meters, containing about 86 different types of buildings. The main building types are teaching buildings, office buildings, libraries, canteens, and dormitories. As the university was built long ago, thus some buildings such as teaching buildings, libraries, dormitories, and canteens have been constructed or reconstructed in recent years.

Study Methods

This questionnaire was designed according to the professional characteristics of architecture, the course characteristics, and the meeting point with energy-conservation and emission-reduction. A list of eight questions for the questionnaire has been prepared, all questions are multiple-choice questions and ranking problems, and no subjective questions are set. This questionnaire consisted of 8 questions in total and is divided into two parts. The first part (2 questions) consisted of questions about the respondents' basic identification information, including gender and grade level. The second part (6 questions) included questions about their daily study and life in school related to energy-saving and emission reduction of green buildings. The questionnaire was designed on the Tencent questionnaire webpage and sent to the respondents through a web link.

As shown in Fig. 1, the number of respondents was 140 students, including 34 (24.3%) Sophomores, 30 (21.4%) Juniors, 35 (25.0%) Seniors, and 41 (29.3%) Graduates. Among them, the number of males was

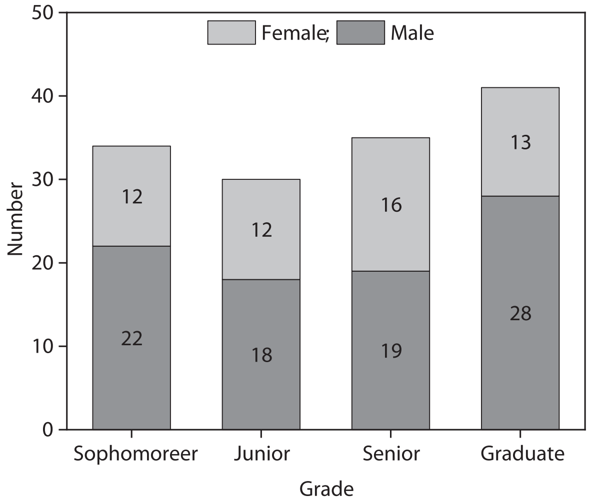

Fig. 1. Grade and gender of participants.

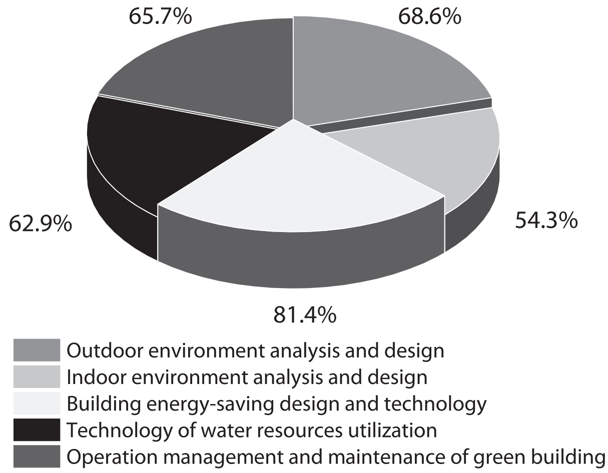

Fig. 2. Main research contents of green building.

87 (62.1%), and the number of females was 53 (37.9%). The statistical results were exported and analyzed using SPSS software.

Stability of the Study Methods

To verify the stability of the study methods, the Cronbach alpha coefficient was extracted to analyze the study. A Cronbach alpha coefficient is a statistic that is the mean of the discounted half reliability coefficients obtained from all possible methods of item classification, and is the most commonly used reliability measure [22]. Usually, the value of Cronbach alpha coefficient is between 0 and 1. If the alpha coefficient does not exceed 0.6, it is generally considered to have insufficient internal consistency reliability. If Cronbach alpha coefficient reaches 0.7-0.8 indicates that the scale has considerable reliability, and getting 0.8-0.9 indicates that the scale has excellent reliability [23].

Results and Discussion

Stability Analysis

The Cronbach alpha coefficient of questions A.1-A.2 was 0.814, which was greater than 0.8, indicating the high quality of reliability of the study data (Table 1). The Cronbach alpha coefficient of questions B.1-B.6 was 0.750, which was greater than 0.7, indicating the reliability quality of the study data was high. The total score of questions A.1-B. 6 was 0.856, which comprehensively demonstrated that the reliability quality of this questionnaire was high, which was an acceptable value for the current study and could be used for further analysis.

Questionnaire Analysis

The first question was **B. 1. What technologies do you think energy saving and emission reduction of green building design should focus on?** Out of 140 students, 81.4% of the 140 students chose the building energy-saving design and technology (Fig. 2). This technology includes building energy saving, equipment energy saving, lighting and lighting, renewable energy utilization technology, and other contents, which are more directly related to energy-saving and emission reduction. With the more integrated knowledge system, the highest proportion of students chooses the building energy-saving design and technology. In addition to 54.3% of students who chose indoor environment analysis and design, the percentage of students who chose outdoor environment analysis and design, operation management and maintenance of green buildings, and technology of water resources utilization were 68.6%, 65.7%, and 62.9%, respectively.

The second question was **B. 2. To deepen the green building energy-saving learning, which courses should be focused on learning?** Among the 140 students, the percentage of those who chose building materials, ecological building design, and introduction to green building were similar, which were 75.7%,

Table 1. Coefficients of stability using Cronbach's alpha test.

Cronbach alpha coefficient	The questions	The field
0.814	A.1-A.2	Gender and grade of participants
0.750	B.1-B.6	Attitudes toward the energy-saving and emission reduction of green buildings
0.856	A.1-B.6	Total

74.3%, and 74.3 %, respectively (Fig. 3). The percentage of students who chose architectural design was in the middle, at 52.9%. Fewer students chose construction equipment and architectural physics, with 42.9% and 40.0%, respectively.

The third question was **B. 3. What kind of teaching method about green buildings are you interested in?** Among the 140 students, the proportion of those who chose experimental teaching was 74.3% (Fig. 4). The results showed that students are more interested in experimental teaching, so the proportion of experimental teaching can be increased to improve students' learning and mastery of energy-saving and emission reduction through continuously practicing skills. The ratio of students who chose project teaching and theory teaching followed closely, at 64.3% and 55.7%, respectively. Internship teaching was selected by the least proportion of students, 47.1%. Internship teaching is where students are engaged in practical work on the spot of enterprises under the organization and guidance of teachers, and have obtained relevant practical knowledge and skills.

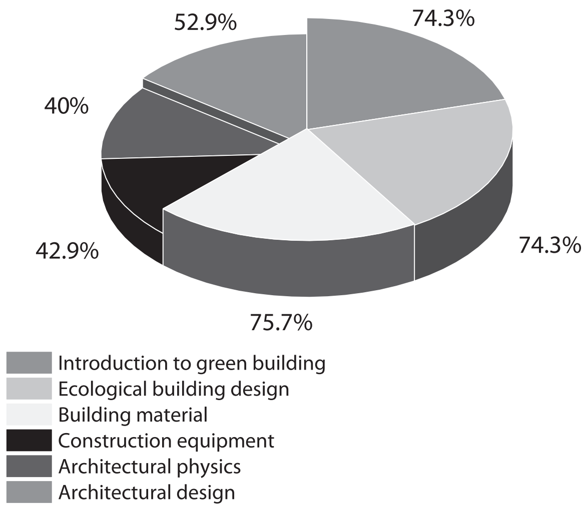

Fig. 3. Major courses related to green building in architecture.

Although architecture students can get more practical design projects through internship teaching, this type of teaching method is mostly arranged in the graduation year, so fewer students chose it.

The fourth question was **B. 4. Which majors do you think play a more significant role in energy-saving and emission reduction of green buildings?** Among the five majors in the figure, 75.7% of students chose architecture as the major with the most significant role in energy-saving and emission reduction of green buildings (Fig. 5). On the one hand, it is related to the professional characteristics of architecture. On the other hand, because the participants are students of architecture, they usually prefer their majors. The second highest overall ranking was heating ventilation air conditioning (HVAC) engineering, with 35.8% of students ranking it second and 41.4% ranking it third. Civil engineering was ranked third overall, with 40.0% of students ranked it second and 31.4% ranked it third. The fourth overall ranked was water supply and drainage engineering, with 64.8% of students ranking it fourth. The percentage of students who organized the major of engineering management fifth was the highest among the five majors, at 87.3%.

The fifth question was **B. 5. Please select the characteristics of the following buildings**. There are five types of campus buildings listed in this question: teaching building, office building, library, canteen, and dormitory (Fig. 6). There are four types of building characteristics: large building volume, large flow of people, high energy consumption, and many building components that can apply energy-saving and emission. The buildings with the most significant number of students who chose the building feature of the large flow of people were the teaching building and canteen, with 87.1% and 85.7%, respectively. The building with the highest proportion of large building volume was the library, with a proportion of 81.4%. For the office building, the percentages of those large building volumes and high energy consumption were more similar, which were 65.7% and 61.4%, respectively.

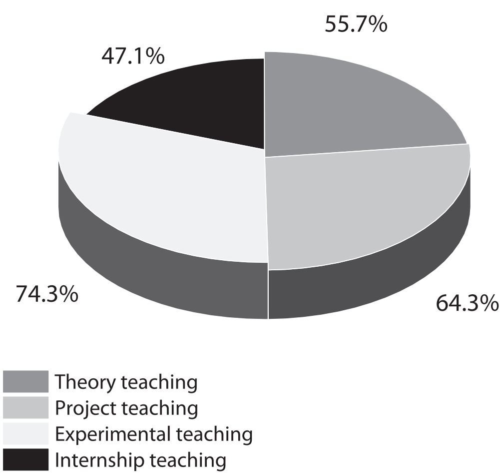

Fig. 4. The teaching method of the green building course.

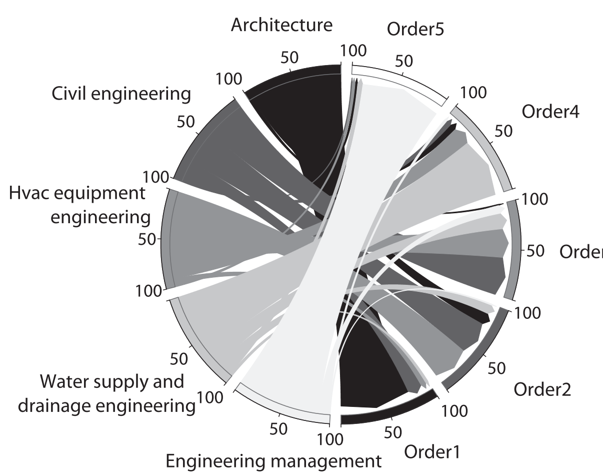

Fig. 5. Majors ordination plot.

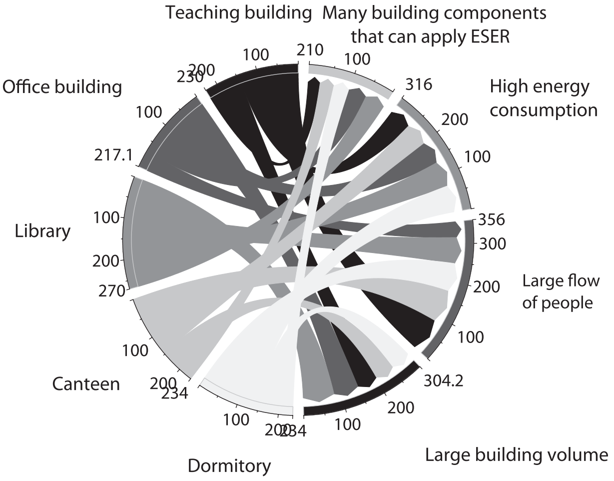

Fig. 6. Characteristics of different buildings on the campus.

For dormitories, the proportions of chosen large flow of people and high energy consumption were similar, which were 72.9 % and 70.0 %, respectively. All five building types with the highest selection rate do not have the characteristic of many building components that can apply energy-saving and emission-reduction technology, which may be due to students' unfamiliarity with energy-saving and emission-reduction measures. This building characteristic with the highest selection rate was the library at 52.9%, and the lowest was the teaching building at 31.4%.

Note: ESER, energy-saving, and emission reduction

The sixth question was **B. 6. Please click on the places where you spend more time in school.** Among the students' options, it was evident that the library and the dormitory were where students spent most of their time each day (Fig. 7). The library provides a suitable place for students to study because of the large number of coursework in architecture, and a dormitory is a place where students live and rest. In addition to these two places, students spent more time in the No. C comprehensive building because it is a combined office and teaching building with specialized classrooms for architecture students to complete their professional work. In addition, students also spend relatively more time in the No. 2 teaching building and the stadium.

Cross Analysis

Table 2 shows the results of the Chi-square (x^2) test on the responses to the technical measures for energy-saving and emission reduction in green buildings. Regarding gender, the proportion of male and female students who chose different technical measures was roughly the same, with a chi-square value of 1.911, $p = 0.752>0.05$, which did not show significance, implying that the gender of male and female students had no differential effect on the research results.

Analyzed in terms of grade levels, the technical measures with the highest selection rates were not the same in the four grades. From the Chi-square test, it could be seen that the result of different grades for different energy-saving and emission-reduction technology measures was 45.316, $p<0.001$ was much less than 0.01, which showed a highly significant effect on the variability of the research results.

Table 3 shows the results of the chi-square (x^2) test for the responses to the different green building courses. Regarding gender, the proportion of male and female students who chose different green building courses was roughly the same, with a chi-square value of 3.392, $p = 0.640>0.05$, which did not show significance, implying that there was no differential effect of gender on the results.

For grade level, the sophomore had the highest number of participants who chose the course introduction to green building with 25.5%. Junior had the highest percentage of people who chose building materials, with 21.3% respectively. The highest percentage of seniors and graduates chose ecological building design, with 22.7% and 22.1%, respectively. The chi-square test

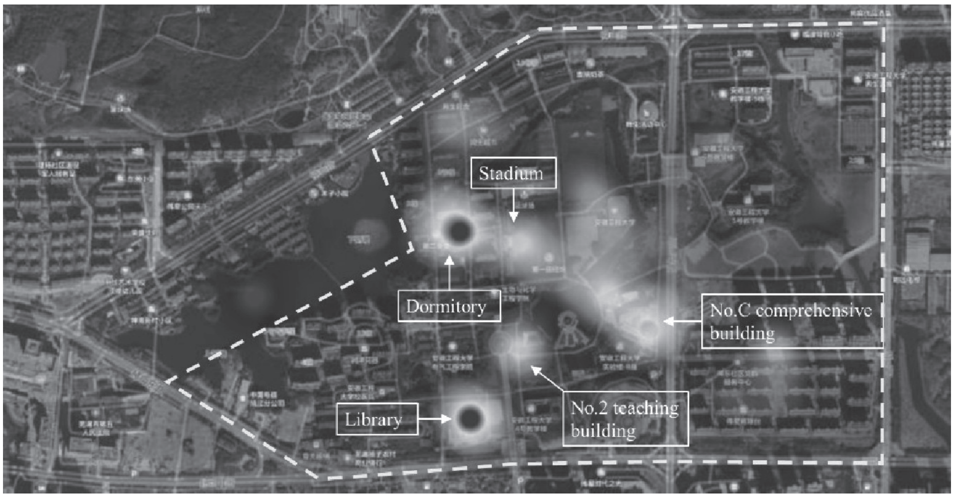

Fig. 7. Thermal map of student trail.

Table 2. Chi-square test results of question B.1.

Variable		What technologies do you think energy-saving and emission reduction of green building design should start from?									
		Outdoor environment analysis and design		Indoor environment analysis and design		Building energy-saving design and technology		Technology of water resources utilization		Operation Management and Maintenance of Green Building	
		N	%	N	%	N	%	N	%	N	%
Gender	Male	58	20.8	48	17.2	66	23.7	56	20.1	51	18.3
	Female	38	20.3	28	15.0	48	25.7	32	17.1	41	21.9
	Total	96	20.6	76	16.3	114	24.5	88	18.9	92	19.7
	Chi-square (χ^2) = 1.911 Sigma (σ) = 0.752										
Grade	Sophomore	28	19.6	23	16.1	36	25.2	25	17.5	31	21.7
	Junior	13	31.7	5	12.2	8	19.5	8	19.5	7	17.1
	Senior	21	17.9	20	17.1	32	27.4	23	19.7	21	17.9
	Graduate	34	20.6	28	17.0	38	23.0	32	19.4	33	20.0
	total	96	20.6	76	16.3	114	24.5	88	18.9	92	19.7
	Chi-square (χ^2) = 45.316 Sigma (σ)<0.001**										

Note: * p<0.05, ** p<0.01

Table 3. Chi-square test results of question B. 2

Variable		To deepen green building energy-saving learning, which courses should focus on learning?											
		Introduction to green building		Ecological building design		Building material		Construction equipment		Architectural physics		Architectural design	
		N	%	N	%	N	%	N	%	N	%	N	%
Gender	Male	60	19.5	59	19.2	66	21.4	40	13.0	33	10.7	50	16.2
	Female	44	22.4	45	23.0	40	20.4	20	10.2	23	11.7	24	12.2
	Total	104	20.6	104	20.6	106	21.0	60	11.9	56	11.1	74	14.7
	Chi-square (χ^2) =3.392 Sigma (σ)=0.640												
Grade	Sophomore	40	25.5	29	18.5	35	22.3	17	10.8	12	7.6	24	15.3
	Junior	9	19.1	8	17.0	10	21.3	7	14.9	8	17.0	5	10.6
	Senior	24	20.2	27	22.7	24	20.2	13	10.9	12	10.1	19	16.0
	Graduate	31	17.1	40	22.1	37	20.4	23	12.7	24	13.3	26	14.4
	Total	104	20.6	104	20.6	106	21.0	60	11.9	56	11.1	74	14.7
	Chi-square (χ^2) = 11.153 Sigma (σ) = 0.038*												

Note: * p<0.05, ** p<0.01

results showed that the chi-square value of different grades for different green building courses was 11.153, p = 0.038<0.05, which showed significance, implying that different rates had a significant effect on the variability of the research results.

Table 4 shows the results of the chi-square (x^2) test of the responses to the different teaching methods of green building courses. Regarding gender, both male and female students chose the four different teaching methods in the same order: experimental teaching> project teaching> theory teaching> internship teaching. The chi-square value was 0.832, p = 0.842, which was much greater than 0.05, indicating that the genders made no difference to the choice of the results of the different teaching methods for the green building courses.

The analysis of grade level had a chi-square value of 5.945, with p = 0.745, which was much more significant than 0.05, indicating that none of the grade levels had a significant impact on the choice of teaching methods for different green building courses.

Table 4. Chi-square test results of question B.3.

Variable		What kind of teaching method about green buildings are you interested in?							
		Theory teaching		Project teaching		Experimental teaching		Internship teaching	
		N	%	N	%	N	%	N	%
Gender	Male	49	23.8	55	26.7	60	29.1	42	20.4
	Female	29	22.0	35	26.5	44	33.3	24	18.2
	Total	78	23.1	90	26.6	104	30.8	66	19.5
	Chi-square (χ^2) =0.832 Sigma (σ)=0.842								
Grade	Sophomore	24	23.8	20	19.8	36	35.6	21	20.8
	Junior	8	25.8	11	35.5	8	25.8	4	12.9
	Senior	20	21.7	25	27.2	27	29.3	20	21.7
	Graduate	26	22.8	34	29.8	33	28.9	21	18.4
	total	78	23.1	90	26.6	104	30.8	66	19.5
	Chi-square (χ^2) = 5.945 Sigma (σ) = 0.745								

Conclusions

University is an important place to cultivate architectural talents and devote to energy-conservation and emission-reduction, so the cultivation of students is very important. This study analyzed the perceptions of architecture students regarding the curriculum related to energy-saving and emission reduction of green buildings, as well as the campus buildings, with the following main conclusions.

(1) The Cronbach alpha coefficient of question A.1-A.2 was 0.824. the Cronbach alpha coefficient of questions B.1-B.6 was 0.770. The total score of questions A.1-B.6 was 0.856, which collectively indicated that this questionnaire had high reliability and could be used for further analysis.

(2) For questions B.1 to B.3, the building energy-saving design and technology (81.4%), building materials courses (75.7%), and experimental teaching methods (74.3%) were the most answered by respondents. There was 75.7% of respondents considered that architecture was the major that plays the most significant role in energy-saving and emission-reduction of green buildings. In addition, the question of B.6 showed that students spent more time in libraries and dormitories, thus the promotion of energy-saving and emission-reduction technologies can focus on these building types. (3) Through the Chi-square test, the p-value of different grades on technologies choice of energy-saving and emission reduction of green buildings was less than 0.001, which was much smaller than 0.01, indicating that different grades had a highly significant effect on the research results of question B.1. The Chi-square value of different grade levels on the green building courses was 0.038, and the p-value was less than 0.05, which mean that different grade levels significantly affect the results of question B.2.

Acknowledgments

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Conflict of Interest

The authors declare no conflict of interest.

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