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Article

Analysis of sustainable building design concept (SBDC) adoption in current China's architecture, engineering, and construction (AEC) related higher education curriculum

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Abstract: The architecture and engineering industry employs resource-efficient sustainable building design (SBDC) to reduce greenhouse gas emissions and mitigate environmental damage. This study examines the understanding and practice of SBDC among Chinese architecture students. A survey of 555 undergraduates from China's architecture universities was conducted. Two independent and seven dependent variables were analyzed to evaluate the impact of academic stages and practical experiences on students' awareness. The findings reveal that over 70% of respondents consider SBDC important in architecture. More than half have taken courses with over 30% SBDC content. However, 45.85% of respondents only have a basic understanding of SBDC. This result underscores the significance of educational disparities, this insufficiency is likely due to inadequate coverage and representation of SBDC in the curriculum. Our study highlights the necessity of enhancing SBDC-related education within the current curriculum framework to ensure all students receive a systematic and comprehensive knowledge of sustainable building design.

Keywords: Chinese institutes; curriculum design; Chinese architecture students; resource-efficient designs; practical experiences

1. Introduction

Global climate change has emerged as one of the most pressing challenges in the 21st century for each country. Since the era of the Industrial Revolution commenced (Yang et al., 2022), the significant acceleration in greenhouse gas emissions has led to global temperature rise, the increasing frequency of extreme weather events, the unavoidable increase of sea levels, and the unpredictable destruction of biodiversity. According to the Intergovernmental Panel on Climate Change (IPCC) (Lemke et al., 2007), temperatures could rise to catastrophic levels by the end of this century since the greenhouse effect could not be mitigated. The architecture, engineering and construction (AEC) industry, as a major consumer of energy and emitter of greenhouse gases (Zheng et al., 2021), plays a critical role in environmental protection that sustainable building concept could be treated as a crucial methodology of reducing environmental damages from greenhouse gas and dealing with climate change. Among the participants of the AEC industry, resource-efficient designs and technologies have emerged and become common tools to assist the decrease in carbon, such as building information modeling, sustainable building design concept (SBDC) and Environment, Society, and Governance (ESG) concept.

SBDC refers to the design concept that focuses on minimizing the negative environmental impacts while providing better living and working environments for building users (Katiyar et al., 2021). The rise of SBDC was mainly driven by the ever-increasing environmental awareness of common users; the improvement of building technologies and forced governmental instruction both contributed to the promotion of SBDC (Shahid et al., 2023). In the view of technics, SBDC involves both environmental, economic, and social factors (Katiyar et al., 2021) in the whole life of buildings from planning to operating, sometimes could contribute to disposal, to minimize resource consumption and environmental impacts while enhancing the efficiency and comfort of buildings. This includes principles such as reducing energy consumption and carbon emissions through optimized building design to reduce resource waste and environmental pollution (Li et al., 2023), moreover, SBDC played an important role in the circular economy principle that protects natural ecosystems and reducing the impact of building activities on soil, air (Khahro et al., 2021). The potential value of SBDC in the view of biodiversity could be summarized as improving bio-environmental quality and improving the health and comfort of occupants (Bian et al., 2024).

SBDC began emerging in the early 20th century, primarily in Europe and North America, focusing on energy conservation, environmental protection, and the long-term benefits of buildings (Vagtholm et al., 2023). As environmental awareness increased in the mid to late 20th century, more countries and regions introduced relevant policies and standards, with Europe and North America leading the development of sustainable building design with standards such as the United States (US)'s Leadership in Energy and Environmental Design (LEED) (Council, U. G. B., 1998) and the United Kingdoms (UK)'s Building Research Establishment Environmental Assessment Method (BREEAM) (Attia et al., 2018). In the early 21st century, the global practice of SBDC deepened, with many countries promoting renewable energy applications and green building technology development (Strielkowski et al., 2021). Currently, major developed countries have published comprehensive green building regulations and standards systems, with continuous innovation in green building technologies and high market acceptance. In China, SBDC is encouraged by traditional sectors with increasing market demand and significant value in environmental protection. Since SBDC has been promoted and become one compulsory standard of AEC projects in the Chinese market, many new SBDC clauses and certificates with higher requirements were supplied (Zhang et al., 2018). However, the development of SBDC shows significant regional differences varied by economic conditions and other factors (Wang, et al., 2023).

In the context of current global challenges, enhancing the relevance and impact of Sustainable Building Design Concepts (SBDC) education is crucial for mitigating climate change (Denison, 2017). SBDC education not only reduces the construction industry's carbon footprint but also promotes the adoption of green building standards and influences policy development (Wang, 2018). Integrating SBDC comprehensively into architectural curricula can cultivate future architects who are equipped to address environmental challenges, thereby enhancing the reputation of educational institutions (Winter, 2022). This initiative aligns with the United Nations Sustainable Development Goals (SDGs) and contributes to economic and health benefits (Raykov, 2011). It is imperative that educators, policymakers, and industry professionals collaborate to provide the necessary resources, support, and practical opportunities to advance SBDC education (Fowler, 2013).

2. Literature review

China's architectural education system originated in the early 20th century and has progressively developed and improved by continuously absorbing and integrating advanced foreign experiences (Bailey et al., 2013). Nowadays, the architecture educational focus of higher education institutes shifted foundational courses such as architectural design, architectural history and theory, and architectural technology and materials to develop students' advanced professional skills (Wang, 2015). Many prestigious institutions like Tsinghua University and Tianjin University offer courses in green building technology, ecological urban planning, and sustainable building materials to cultivate students' environmental awareness and sustainable design capabilities (Xue, 2005).

In the old-school architectural curriculum adopted by most of China's higher education institutes, courses specifically dedicated to SBDC are relatively few compared to traditional design courses, which are limited in aesthetic and functional focuses, instead of systematic learning regarding environmental impacts and resource utilization (Wang, 2018). The existing undergraduate curriculum framework offered in universities aims to establish a solid talent-back foundation for AEC industry with several repeat personnel training on complex projects which sacrificed the culture enlightenment on sustainability (Winter, 2022). However, the curriculum of master level related to AEC industry highlighted the importance of environmental friendliness and resource conservation as the key of the achievement of one AEC project which led to a huge crack on China's undergraduate level students and students with higher degrees (Xie et al., 2021).

In China, a few leading institutes noticed the gap between ideologies and practices; hence, some innovative design studios related to sustainable design theory application into actual projects offered in their curriculum. For example, scientometric tools (Yuan et al., 2024), BIM (Zou et al., 2017) and UAVs (Grosso et al., 2020) were applied to the study of sustainable building design. Among AEC industry, participants had gleaned more information on the demand market than sector officers which contributed to the commencement of sustainability competitions and pushed future talents to foster their innovative ability. In some practices, case studies of defined SBDC projects involved in professional courses demonstrated additional value in helping students understand the structured concept of SBDC and brightening their view of cutting-edge sustainable design technologies (Dubey et al., 2017).

3. Research objectives, questions, hypothesis and theoretical framework

3.1. Research objectives

RO1: To assess the level of understanding of Sustainable Building Design

Concepts (SBDC) among undergraduate students in architecture-related majors in China. The goal is to gauge students' mastery of SBDC to inform curriculum design.

RQ2: To analyze the impact of different academic years and practical experience on students' understanding of SBDC. The objective is to evaluate whether students' comprehension of SBDC improves with academic progression and increased practical experience, thereby optimizing course content and teaching methods.

RQ3: To investigate the coverage of SBDC content in the current curriculum and its impact on teaching effectiveness. The aim is to examine the proportion of SBDC content in the curriculum and its effects on student satisfaction and understanding, providing empirical support for curriculum improvement.

3.2. Research questions

RQ1: What is the level of understanding of Sustainable Building Design Concepts (SBDC) among undergraduate students in architecture-related majors in China?

RQ2: How do academic stages and practical experience influence students' understanding and ability to apply SBDC?

RQ3: How does the coverage of SBDC content in the current curriculum affect student satisfaction and understanding?

3.3. Research hypothesis

RH1: Students' understanding of SBDC significantly improves as they progress through academic years.

RH2: Participation in practical projects and studio experiences has a significant impact on students' understanding and ability to apply SBDC.

RH3: The proportion of SBDC content in the curriculum has a significant impact on student satisfaction and understanding levels.

3.4. Theoretical framework

Based on the above content, the theoretical framework of the article is as **Figure 1**:

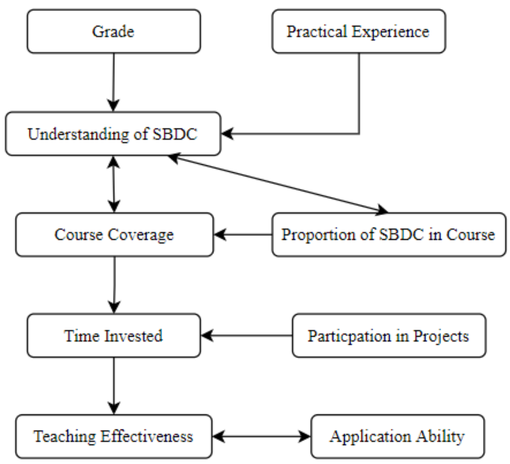

Figure 1. Theoretical framework.

4. Method

4.1. Research design

This survey aims to assess the understanding, awareness, coverage, and practical application of sustainable architectural design among students in Chinese architecture programs. By analyzing data from students across different academic years and their participation in relevant activities, the authors evaluated the effectiveness of curriculum design and teaching methods, providing data support for further educational improvements. The questionnaire (see the Appendix) encompassed questions covering students' understanding and awareness of sustainable architectural design, the extent of course coverage, and satisfaction levels. Each question was designed as a single-choice question to ensure data comparability and ease of statistical analysis.

4.2. Participants

The survey targeted 555 undergraduate students from architecture schools across various universities in China. These students come from different regions and institutions, bringing diverse learning experiences in sustainable architectural design courses and practices to the survey. These students come from universities in ten different regions of China and all belong to architecture-related colleges, providing a comprehensive reflection of the current situation (McMillan, 1996). The selection of these students enhances the reliability and validity of the data, reduces bias, and allows for complex statistical analysis (Johnson et al., 2019). Additionally, it increases the diversity and depth of the data, thereby revealing the characteristics and needs of different subgroups (Leavy, 2022). Finally, it improves the robustness of data analysis and the generalizability of the research findings, ensuring the reliability and broad applicability of the study's conclusions (Patten, 2016).

4.3. Data collect and analysis

4.3.1. Data collect

The study utilized a questionnaire to collect data. This questionnaire gathered information on students' grade levels, practical experience, understanding of SBDC, recognition of the importance of SBDC, the proportion of SBDC content in the curriculum, course coverage, teaching effectiveness, time invested in learning, and participation in related practical projects or studio experiences (Fraenkel, 1993). Each section employed multiple-choice questions, rating scales, and open-ended questions to comprehensively understand students' specific situations and perceptions in these areas. This design allowed for a systematic collection and analysis of the factors influencing SBDC teaching effectiveness (Fowler, 2013).

Data collection was conducted using the online survey platform Wenjuanxing to facilitate broad distribution and efficient collection of responses. Most questions in the questionnaire used a Likert scale for scoring, such as a 1 to 5 rating, indicating varying levels of satisfaction from "very dissatisfied" to "very satisfied". Additionally, a few questions were designed as single-choice questions, requiring respondents to select the most appropriate answer from multiple options. Finally, a limited number of open-ended questions were included to allow respondents to provide detailed opinions and suggestions, supplementing the quantitative data.

4.3.2. Data analysis

The data analysis methods employed will directly impact the accuracy and validity of the research conclusions. To comprehensively understand the understanding, awareness, coverage, and practical application of sustainable architectural design among students in Chinese architecture programs, this study utilized cross-tabulation analysis to analyze the survey data. This method not only illustrates the changes in students' awareness across different academic stages but also evaluates the impact of participation in sustainable architecture-related activities on students' understanding and awareness (Babbie, 2020).

Cross-tabulation analysis is a method used to analyze the relationships between two or more variables. We observed the frequency distribution under different variable combinations, revealing the associations between variables. In this study, cross-tabulation analysis was primarily used to compare responses from students of different academic years and those who have participated in relevant activities on various questions. The specific analysis steps are as follows:

Variable selection: Academic year and participation in activities were selected as independent variables, while understanding level, awareness of importance, course content proportion, course coverage, effectiveness of course delivery, time invested in learning, and involvement in practical projects or studio practices were selected as dependent variables.

Constructing cross-tabulation tables: For each dependent variable, a cross-tabulation table was constructed with the independent variables, calculating the frequency and percentage for each cross-cell. For instance, for the question "How would you rate your understanding of sustainable architectural design?" we constructed a frequency and percentage table of students' responses across different academic years and participation statuses (Agresti, 2018).

Data reliability testing: Reliability analysis was conducted to measure the reliability of the survey responses, determining whether the sample genuinely reflects the scale items. Reliability analysis is usually applied to scale data; non-scale data typically do not undergo reliability analysis. The commonly used reliability analysis indicator is Cronbach's alpha (**Table 1**), whose value range and interpretation are as follows (Cronbach, 1951):

Table 1. Cronbach's alpha.

Reliability Values	Interpretation
＞0.8	Indicates excellent reliability, suggesting that the test or scale has a very high level of consistency.
＞0.7	Indicates acceptable reliability, meaning the scale is quite reliable and suitable for research and practical applications.
＞0.6	Suggests that the scale needs revision but still holds some value. Specific items may require improvement to enhance reliability.
＜0.6	Indicates that the scale needs to be redesigned as the reliability is low and it cannot effectively measure the research subject.

4.4. Validity

To evaluate the internal consistency of the scale, Cronbach's alpha reliability analysis was used to test the data after collection. A total of 555 samples were used, with scores on 10 items. By calculating the variance of each item and the variance of the total score, these values were substituted into the following formula:

$$a = \frac{k}{k-1}\left(1 - \frac{\sum_{i=1}^{k}\sigma_i^2}{\sigma_T^2}\right)$$

Where k is the number of items, σ_i^2 is the variance of the i-th items, σ_T^2 is the variation of total score. The Cronbach's alpha value is 0.837 (above 0.8) could define the result as excellent reliability in the methodological level (Raykov, 2011). This suggests that the data has very high consistency, and the collected samples are authentic and suitable for research purposes. Furthermore, the data collected in this study holds significant research value and can be used for future studies, providing a solid foundation for further investigation.

5. Results and summary

5.1. Questionnaire results

In this study, the authors analyzed two independent variables and seven dependent variables (as detailed in **Figure 2** below). These variables were chosen to evaluate students' understanding and awareness of sustainable architectural design. The independent variables include the students' academic year (ranging from first to fifth year) and whether they have participated in internships or research projects related to sustainable architecture. The dependent variables included students' understanding of sustainable architectural design, their perception of its importance, the proportion of course content dedicated to it, the extent of course coverage, the effectiveness of course delivery, weekly study hours, and whether the course offers relevant practical projects or studio experiences (Weyant, 2022).

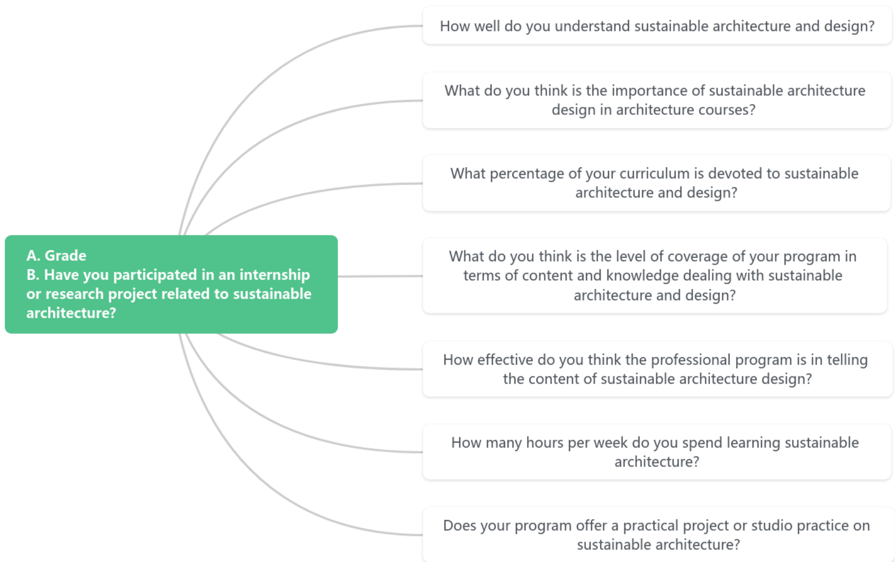

Figure 2. Cross-analysis variables.

The selection of grade level and practical experience as independent variables is based on their reflection of differences in students' knowledge accumulation and practical operation skills. This choice allows for the examination of the curriculum's impact on students at different stages and the effectiveness of practical components in teaching. The seven dependent variables include the level of understanding of SBDC, recognition of its importance, the proportion of SBDC content in the curriculum, coverage, teaching effectiveness, time invested in learning, and participation in practical projects. These variables evaluate the effectiveness of SBDC teaching from multiple perspectives, such as knowledge mastery, learning attitudes, curriculum design rationality, and practical application ability. Consequently, this approach can provide insights into the current state of SBDC education in architecture-related higher education courses in China and identify areas for improvement (Krosnick et al. 2018).

5.1.1. Q1: How well do you understand sustainable architecture and design?

Table 2. Cross tabulated data for the Q1 with grade level and participation in sustainable building design practices.

X\Y	Little understanding	Not too much understanding	Fair understanding	Somewhat understanding	Very much understanding
First-grade/Yes	8.93%	14.29%	53.57%	5.36%	17.86%
First-grade/No	9.55%	38.20%	44.94%	5.06%	2.25%
Second-grade/Yes	6.67%	16.67%	33.33%	26.67%	16.67%
Second-grade/No	10.07%	36.69%	45.32%	5.76%	2.16%
Third-grade/Yes	6.67%	6.67%	70%	6.67%	10%
Third-grade/No	15%	26.67%	40%	13.33%	5%
Fourth-grade/Yes	0.00%	9.09%	45.45%	18.18%	27.27%
Fourth-grade/No	14.29%	47.62%	33.33%	4.76%	0.00%
Fifth-grade/Yes	18.75%	6.25%	56.25%	6.25%	12.50%
Fifth-grade/No	14.29%	35.71%	35.71%	7.14%	7.14%

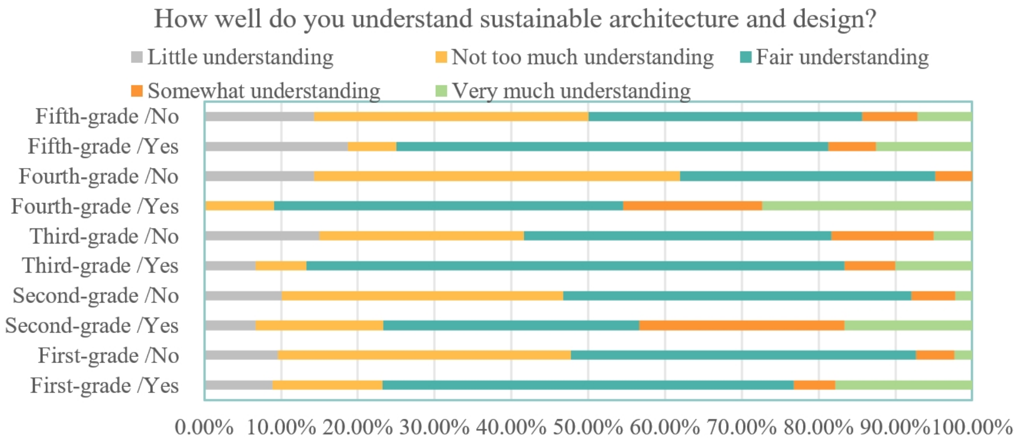

Figure 3. Stacked graph of the Q1 with grade level and percentage who have participated in sustainable building design practices.

Table 2 and **Figure 3** demonstrate that both academic year and participation in certain activities (though specific activities are not explicitly mentioned) significantly influence students' understanding of a subject. Firstly, from the perspective of the academic year, students from the first to third year, regardless of whether they participated in activities, predominantly fall into the categories of "generally understand" and "do not understand well". However, as the academic year increases, particularly in the fourth and fifth years, this trend changes markedly. Notably, students in their fourth and fifth years who have participated in activities demonstrate a significantly higher level of understanding, with a greater inclination towards "fairly understand" and "fully understand".

Summary of Q1

This may indicate that with the accumulation of learning experiences and the broadening of perspectives gained through participating in more activities, senior students have a deeper understanding of the subject. Secondly, from the perspective of participation in activities, students who have participated in activities generally show a higher level of understanding across all academic years. Especially in the first, second, and fifth years, the proportion of students who "fully understand" is noticeably higher among those who have participated in activities compared to those who have not. This suggests that participating in activities indeed enhances students' understanding and awareness levels.

5.1.2. Q2: What do you think is the importance of sustainable architecture design in architecture courses?

The analysis reveals several trends regarding students' perceptions across different academic years and their participation in specific activities (**Table 3** and **Figure 4**). From the perspective of the academic year, as student progress through their studies, the proportion of students who rate the importance of the issue as "Very high" or "Higher" generally decreases, while the proportion rating it as "Average" increases during the second and third years before declining again in the fourth and fifth years.

Table 3. Cross tabulated data for the Q2 with grade level and participation in sustainable building design practices.

X\Y	Very low	Low	Average	Higher	Very high
First-grade/Yes	5.36%	1.79%	17.86%	37.50%	37.50%
First-grade/No	3.93%	3.37%	20.22%	52.25%	20.22%
Second-grade/Yes	6.67%	0.00%	10.00%	33.33%	50.00%
Second-grade/No	3.60%	5.04%	26.62%	44.60%	20.14%
Third-grade/Yes	0.00%	3.33%	33%	33.33%	30%
Third-grade/No	5%	6.67%	17%	41.67%	30%
Fourth-grade/Yes	0.00%	0.00%	27.27%	18.18%	54.55%
Fourth-grade/No	14.29%	9.52%	9.52%	52.38%	14.29%
Fifth-grade/Yes	6.25%	6.25%	12.50%	50.00%	25.00%
Fifth-grade/No	14.29%	7.14%	7.14%	64.29%	7.14%

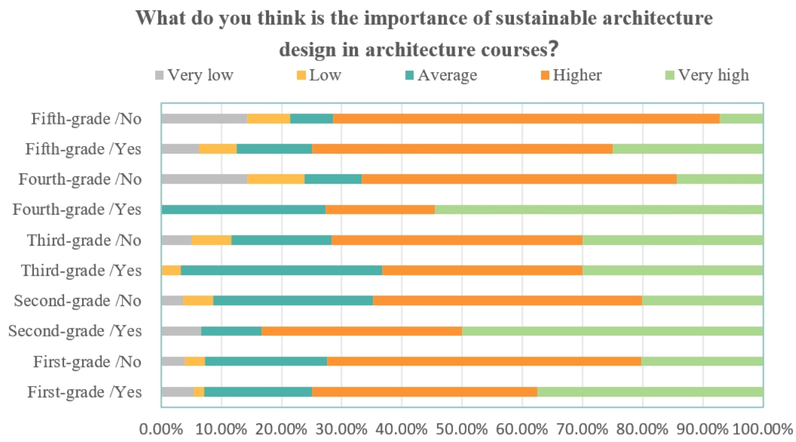

Figure 4. Stacked graph of the Q2 with grade level and percentage who have participated in sustainable building design practices.

Summary of Q2

This indicates that lower-year students may be more inclined to consider certain matters very important, whereas upper-year students tend to adopt a more neutral or conservative attitude. Secondly, considering the factor of participation in specific activities, students who have participated in activities consistently tend to rate the importance of the issue as “Very high” or “Higher” more frequently than those who have not, across all academic years. Notably, in the first and second years, the proportion of students who participated in activities and rated the issue as “Very high” is significantly higher than those who did not participate. This suggests that participation in activities may enhance students’ recognition of the issue’s importance. Specifically, in the first year, over seventy percent of students who participated in activities rated the issue as very important (“Very high” or “Higher”), while nearly ninety percent of non-participating students also rated it as very important. In the second year, the recognition of the issue’s importance among students who participated in activities was higher than among those who did not. However, as student progress to higher academic years, this difference diminishes, particularly among third-, fourth-, and fifth-year students, where participation in activities becomes less significant in influencing their perception of the issue’s importance.

5.1.3. Q3: What percentage of your curriculum is devoted to sustainable architecture and design?

From **Table 4** and **Figure 5**, we can see that students in their first and fourth years are more inclined to participate in current activities. Conversely, the participation rate is notably lower among fifth-year students. This trend suggests that as students approach the end of their academic programs, their engagement in extracurricular or current activities diminishes, possibly due to increased academic pressures or focus on career preparation. The majority of students’ participation proportions fall between 31% and 50%.

Table 4. Cross tabulated data for the Q3 with grade level and participation in sustainable building design practices.

X\Y	0–10%	11–30%	31–50%	51–70%	more than 71%
First-grade/Yes	14.29%	16.07%	30.36%	23.21%	16.07%
First-grade/No	17.98%	29.78%	30.34%	15.73%	6.18%
Second-grade/Yes	6.67%	16.67%	33.33%	16.67%	26.67%
Second-grade/No	31.65%	23.74%	27.34%	9.35%	7.91%
Third-grade/Yes	10%	10%	53.33%	10%	16.67%
Third-grade/No	20%	23.33%	28.33%	18.33%	10%
Fourth-grade/Yes	9.09%	18.18%	18.18%	27.27%	27.27%
Fourth-grade/No	47.62%	23.81%	28.57%	0.00%	0.00%
Fifth-grade/Yes	25%	37.50%	18.75%	0.00%	18.75%
Fifth-grade/No	50%	28.57%	14.29%	7.14%	0.00%

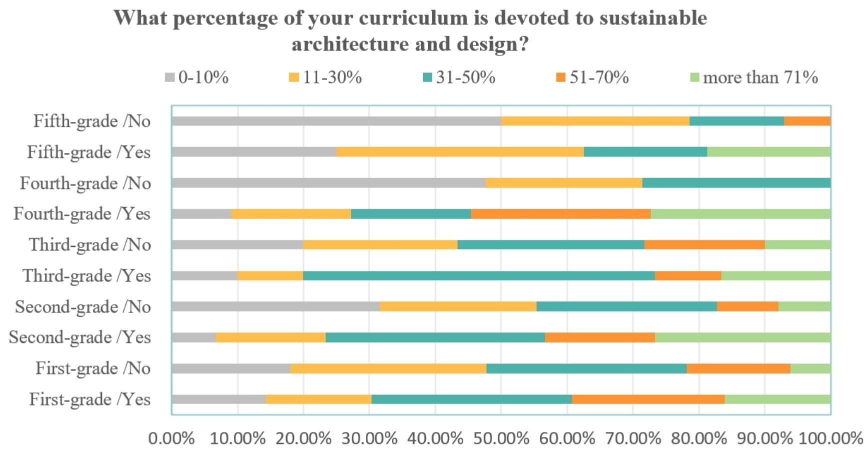

Figure 5. Stacked graph of the Q3 with grade level and percentage who have participated in sustainable building design practices.

Summary of Q3

This indicates a moderate level of engagement across the board, suggesting that while students are involved in activities, they do not overwhelmingly commit a significant portion of their time to these endeavors. This balanced participation could reflect a reasonable distribution of time between academic responsibilities and extracurricular activities. Across all academic years, a significant proportion of students who do not participate in current activities report their participation proportion as 0–10%. This non-participation trend highlights a group of students who are either not interested in or unable to engage in extracurricular activities, which could be due to various factors such as academic workload, personal preferences, or external commitments. The data shows that among second and third-year students, the proportion of students with participation rates of 71% or higher is relatively high. In contrast, this high participation rate is less common among students in other academic years. This suggests that mid-program students may have more opportunities or motivation to engage deeply in activities, possibly due to a more settled academic schedule and increased awareness of the benefits of such engagements.

5.1.4. Q4: What do you think is the level of coverage of your program in terms of content and knowledge dealing with sustainable architecture and design?

Table 5. Cross tabulated data for the Q4 with grade level and participation in sustainable building design practices.

X\Y	Non-Coverage (0)	Smaller portion of coverage	Covering half (50%)	More parts covered	Full coverage (100%)
First-grade/Yes	7.14%	21.43%	28.57%	26.79%	16.07%
First-grade/No	10.67%	36.52%	33.71%	18.54%	0.56%
Second-grade/Yes	3.33%	16.67%	46.67%	16.67%	16.67%
Second-grade/No	20.86%	35.97%	28.78%	10.07%	4.32%
Third-grade /Yes	3.33%	16.67%	50%	16.67%	13.33%
Third-grade/No	15%	25%	35%	23.33%	1.67%
Fourth-grade/Yes	0.00%	36.36%	18.18%	18.18%	27.27%
Fourth-grade/No	19.05%	47.62%	33.33%	0.00%	0.00%
Fifth-grade/Yes	12.50%	56.25%	12.50%	18.75%	0.00%
Fifth-grade/No	35.71%	50%	14.29%	0.00%	0.00%

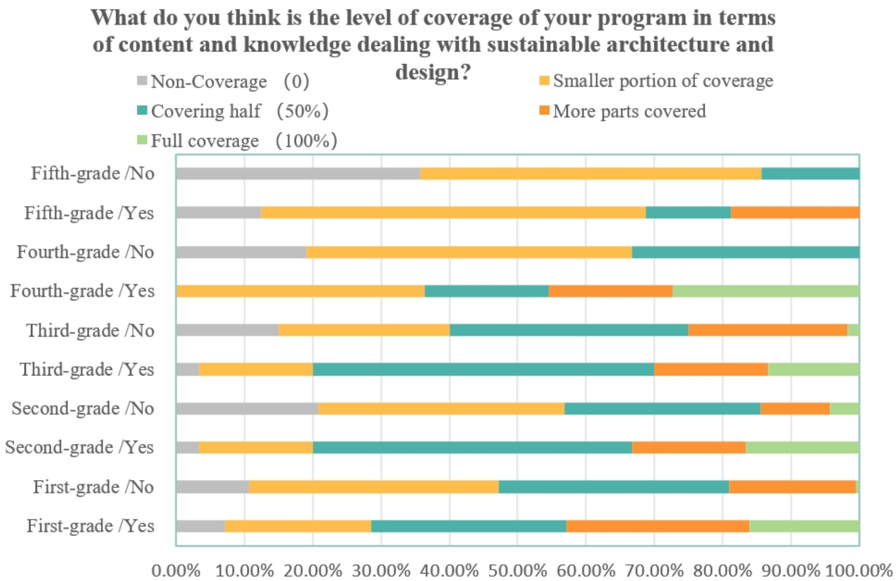

Figure 6. Stacked graph of the Q4 with grade level and percentage who have participated in sustainable building design practices.

Table 5 and **Figure 6** reveal that both academic year (Grade) and participation in internships or research projects related to sustainable architecture significantly influence students' perceptions of course coverage (What do you think is the level of coverage provided by the course?). For first-year students, regardless of whether they have participated in such activities, their views on course coverage are relatively evenly distributed. However, a slightly higher proportion of those who have participated in activities believe the course covers "about half" of the necessary content (28.57% vs. 33.90%).

For second and third-year students, those who have participated in activities are more likely to believe that the course covers “about half” or “quite a lot” of the necessary content, with second-year students showing a particularly high percentage (46.67%) who think the course covers “about half”. In contrast, students who have not participated in activities have more evenly distributed views on course coverage.

For fourth and fifth-year students, due to the smaller sample size, the results may be more variable. However, the data show that fourth-year students who have participated in activities tend to believe the course covers “a little” or “about half” of the necessary content, while those who have not participated generally believe the course covers “a little”. Among fifth-year students, those who have participated in activities primarily think the course covers “quite a lot” or “a little”, whereas non-participants are more likely to think the course covers “a little” or “none at all”.

Summary of Q4

In summary, both academic year and participation in relevant activities influence students’ perceptions of course coverage. Students who have participated in activities are more likely to think the course covers a significant portion of the necessary content (at least half), which may be due to the broader knowledge or experience they gain through these activities. In contrast, students who have not participated in activities may perceive the course coverage as smaller due to their limited knowledge or experience. Additionally, as student progress through their academic years, their perceptions of course coverage show certain trends, likely related to their deeper understanding and familiarity with course content over time. This insight is crucial for educational institutions aiming to design and implement curricula that effectively cover key content areas and meet students’ learning needs at various stages of their academic journey.

5.1.5. Q5: How effective do you think the professional program is in telling the content of sustainable architecture design?

Table 6. Cross tabulated data for the Q5 with grade level and participation in sustainable building design practices.

X\Y	Very dissatisfied	Low satisfaction	Average satisfaction	More satisfied	Very satisfied
First-grade/Yes	3.57%	1.79%	37.50%	33.93%	23.21%
First-grade/No	3.93%	8.99%	53.93%	26.40%	6.74%
Second-grade/Yes	3.33%	6.67%	43.33%	26.67%	20%
Second-grade/No	7.91%	20.86%	45.32%	15.83%	10.07%
Third-grade/Yes	3.33%	10%	40%	30%	16.67%
Third-grade/No	6.67%	10%	40%	30%	13.33%
Fourth-grade/Yes	0.00%	9.09%	54.55%	0.00%	36.36%
Fourth-grade/No	4.76%	28.57%	47.62%	19.05%	0.00%
Fifth-grade /Yes	18.75%	31.25%	31.25%	6.25%	12.50%
Fifth-grade /No	14.29%	14.29%	50%	21.43%	0.00%

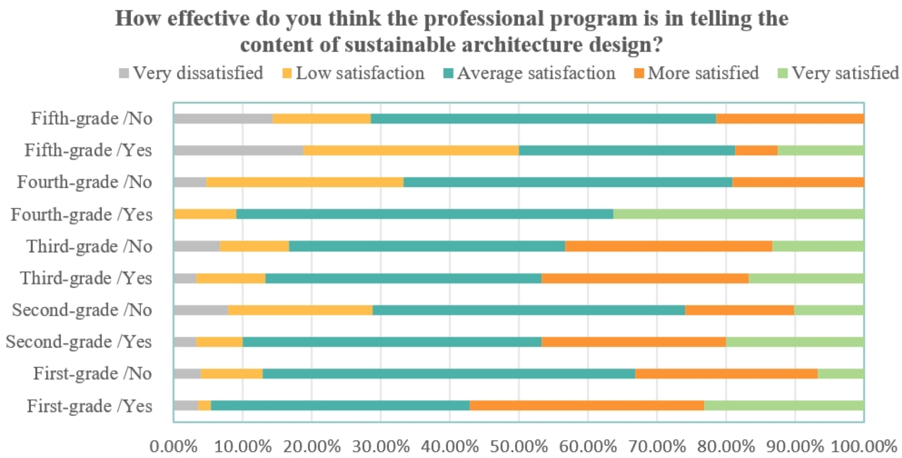

Figure 7. Stacked graph of the Q5 with grade level and percentage who have participated in sustainable building design practices.

The data reveal (**Table 6** and **Figure 7**) that students' evaluations of a dependent variable Y (satisfaction) vary according to their academic year (independent variable X) and whether they participated in a specific activity. Firstly, from the perspective of academic year, students from first to fourth year exhibit lower satisfaction levels when they do not participate in activities compared to those who do. For instance, among first-year students, the proportion expressing low satisfaction is 8.47% without participation, which drops to 1.79% with participation. Similar trends are observed among second, third, and fourth-year students, indicating that participation in activities positively influences student satisfaction.

However, for fifth-year students, satisfaction levels remain relatively low regardless of participation and show significant fluctuations. This could be attributed to the pressures of graduation and job selection, which may affect their overall satisfaction with activities.

Summary of Q5

Regarding the distribution of satisfaction levels, first to third-year students who participate in activities predominantly report "generally satisfied" and "fairly satisfied". In contrast, satisfaction levels among fourth and fifth-year students are more dispersed. This discrepancy may be related to different expectations and focus areas of students at various academic stages. Participation in activities positively impacts student satisfaction, but this effect varies across different academic years. For fifth-year students, particular attention should be paid to their actual needs and psychological state to improve their satisfaction with activities.

5.1.6. Q6: How many hours per week do you spend learning sustainable architecture?

Table 7 and **Figure 8** indicate that both academic year and participation in a specific activity influence the amount of time students spend on that activity each week. Firstly, among first-year students, those who participate in the activity have the highest proportion of spending over 9 h per week (32.14%), followed by those spending 4–6 h (21.43%). In contrast, first-year students who do not participate in the activity most commonly spend less than 1 h per week (29.38%). This suggests that the activity is highly attractive to first-year students, and those who engage are willing to invest a significant amount of time.

Table 7. Cross tabulated data for the Q6 with grade level and participation in sustainable building design practices.

X\Y	Less than 1 h	1–3 h	4–6 h	7–9 h	More than 9 h
First-grade/Yes	14.29%	16.07%	21.43%	16.07%	32.14%
First-grade/No	29.78%	24.16%	24.16%	11.24%	10.67%
Second-grade/Yes	10%	10%	36.67%	20%	23.33%
Second-grade/No	31.65%	27.34%	24.46%	6.47%	10.07%
Third-grade/Yes	10%	13.33%	36.67%	20%	20%
Third-grade/No	31.67%	25%	120%	6.67%	16.67%
Fourth-grade/Yes	9.09%	36.36%	18.18%	0.00%	36.36%
Fourth-grade/No	57.14%	14.29%	23.81%	4.76%	0.00%
Fifth-grade/Yes	37.50%	25%	12.50%	12.50%	12.50%
Fifth-grade/No	35.71%	35.71%	7.14%	7.14%	14.29%

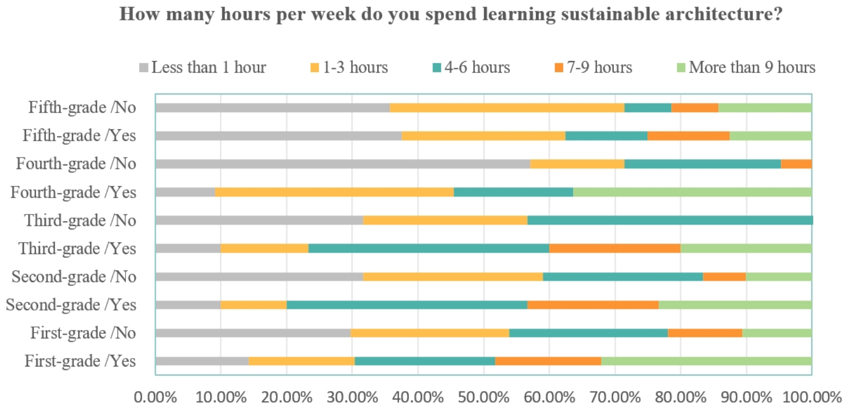

Figure 8. Stacked graph of the Q6 with grade level and percentage who have participated in sustainable building design practices.

For second, third, and fourth-year students, the proportion of those participating in the activity who spend 4–6 h per week is relatively high, at 36.67%, 36.67%, and 36.36%, respectively. Among those not participating, the highest proportion of students spend less than 1 h per week, with 31.65% for second-year and 31.67% for third-year students.

Among fifth-year students, the proportions are more evenly distributed. Participants in the activity most commonly spend either less than 1 h (37.5%) or 4–6 h (25%) per week. Non-participants show a similar distribution, with 35.71% spending less than 1 h and another 35.71% spending 5–7 h per week. This suggests that fifth-year students have a more balanced approach to time allocation for the activity, likely due to the demands of graduation and career preparation.

Summary of Q6

In summary, both academic year and participation in the activity significantly impact the amount of time students dedicate to it each week. First-year and fourth-year students tend to invest more time in the activity, while second, third, and fifth-year students show a more balanced time distribution. Understanding these patterns can help educators and activity organizers tailor their programs to better meet the needs and preferences of students at different academic stages.

5.1.7. Q7：Does your program offer a practical project or studio practice on sustainable architecture?

Table 8. Cross tabulated data for the Q7 with grade level and participation in sustainable building design practices.

X\Y	Yes	No
First-grade/Yes	80.36%	19.64%
First-grade/No	34.83%	65.17%
Second-grade/Yes	66.67%	33.33%
Second-grade/No	30.22%	69.78%
Third-grade/Yes	66.67%	33.33%
Third-grade/No	35%	65%
Fourth-grade/Yes	72.73%	27.27%
Fourth-grade/No	19.05%	80.95%
Fifth-grade/Yes	50%	50%
Fifth-grade/No	14.29%	85.71%

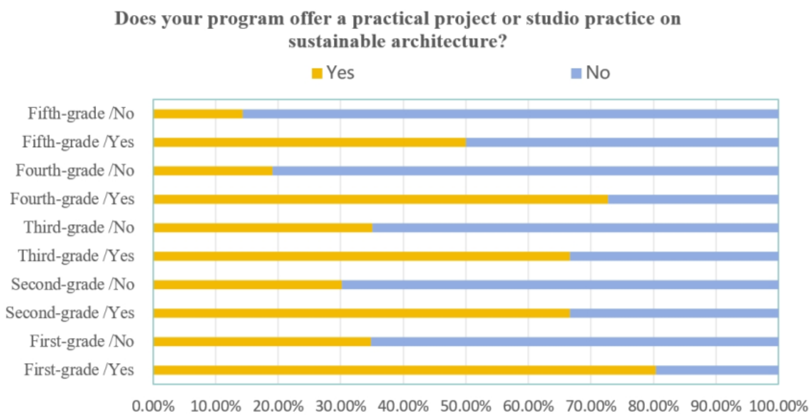

Figure 9. Stacked graph of the Q7 with grade level and percentage who have participated in sustainable building design practices.

Table 8 and **Figure 9** indicate a significant interaction between academic year (Grade) and whether the program offers a practical project or studio practice on sustainable architecture. Among first-year students, 80.36% indicated that their program provides relevant services or opportunities, a proportion significantly higher than those reporting non-availability (19.64%). This suggests that freshmen are inclined to choose programs that offer abundant resources or opportunities from the outset.

Compared to first-year students, the proportion of second-year students responding "yes" slightly declines to 66.67%, but remains high. This implies that as student progress, program-provided resources or opportunities continue to be highly attractive, though some students may begin to prioritize other aspects. The situation for third-year students mirrors that of the second year, with 66.67% reporting that their program offers relevant services or opportunities. The consistency in this proportion suggests that during the second and third years, the availability of program resources or opportunities remains a crucial consideration for students.

In the fourth year, the proportion of students indicating that their program provides resources or opportunities rises to 72.73%, the highest among all years. This increase may be attributed to fourth-year students having clearer career or academic goals, making them more likely to choose programs that meet their specific needs. For fifth-year students, the proportion of those indicating their program offers resources or opportunities drops to 50%, equal to those reporting non-availability. This suggests that by the fifth year, students' needs or expectations may have shifted, or the resources and opportunities provided by the program may no longer align with their needs.

Additionally, as the academic year progresses, the proportion of students reporting non-availability of resources or opportunities gradually increases. This trend reflects that students' needs or expectations become more diverse with higher academic standing, beyond just the availability of certain resources or opportunities.

Summary of Q7

In summary, there is a clear interaction between academic year and whether a program offers specific resources or opportunities. From the first to fourth years, a high proportion of students report that their programs provide these resources or opportunities, but this proportion drops significantly in the fifth year. This finding suggests that program design and selection need to carefully consider students' academic stages and their evolving needs to better support their educational and career aspirations.

6. Analysis and discussion

This study aims to comprehensively understand the perceptions and practices of architecture students regarding sustainable architectural design, while also exploring their views and expectations on related course content and teaching methods. The research seeks to better grasp the current state and challenges of sustainable design education in architecture, providing scientific references and suggestions for future teaching improvements and curriculum design. However, due to variations in course offerings and teaching resources across different universities, students' knowledge and proficiency in this field vary significantly. This survey collected feedback from architecture students of various academic years and institutions to analyze their learning status in sustainable architectural design from multiple angles and levels.

Specifically, the questionnaire covered several aspects, including students' understanding of sustainable architectural design, the extent of course content coverage, practical opportunities, teaching effectiveness, and weekly study time investment. By addressing these questions, the study aims to comprehensively understand students' real experiences and challenges in learning sustainable architectural design and to identify shortcomings in the current education system. Additionally, the survey explored students' satisfaction with existing courses and their suggestions for future improvements. By analyzing student feedback, the study can determine which teaching methods and course setups are more favored and which areas need improvement. These valuable insights and suggestions will provide important references for enhancing the architectural education system, particularly in sustainable design education.

According to the survey data, most respondents are at an "average understanding" (**Figure 10**) level of sustainable architectural design, accounting for 45.85%. This is followed by "not very well understood" at 29.96%. A smaller portion of respondents have a "fairly good understanding" (7.76%) and a "very good understanding" (6.14%) of the field. Those with the least understanding of sustainable architectural design comprise 10.29% of the respondents. Overall, while most respondents have a basic understanding of sustainable architectural design, a significant proportion still have a weak grasp of the field. **Figure 11** show that over 70% of respondents consider the importance of sustainable architectural design in architecture to be high, with 25.45% rating it as very high. This indicates that the importance of sustainable architectural design is widely recognized, reflecting the societal emphasis on sustainable development and the expectation for the architectural industry to reduce environmental impacts and resource consumption.

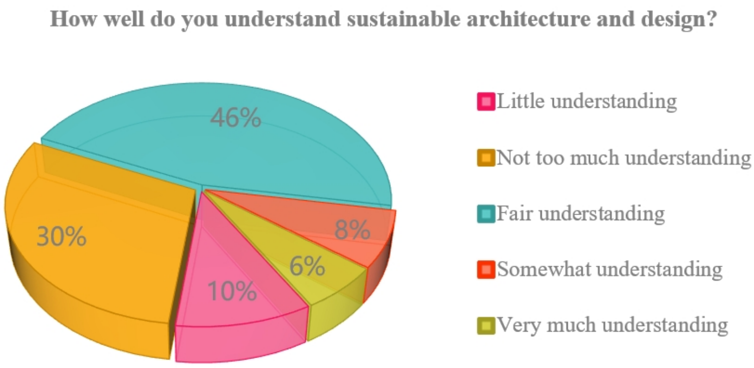

Figure 10. Proportion of students' understanding of sustainable architecture design.

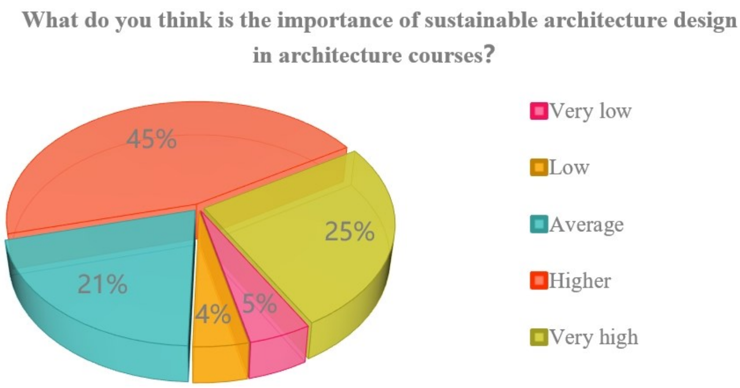

Figure 11. Percentage of students who think sustainable architecture design is important in architecture.

Figure 12 indicates that over half (53.89%) of the respondents indicated that more than 30% of their course content focuses on sustainable architectural design, with the highest proportion being 31–50%, accounting for 29.78%. In contrast, less than a quarter of the respondents (22.02%) reported that sustainable architectural design comprises only 0–10% of their course content. This indicates that a significant portion of courses includes some degree of sustainable architectural design content. Regarding the extent of coverage of sustainable architectural design content and knowledge in the courses (**Figure 13**), 13.18% of respondents believe there is no coverage, 32.85% think the coverage is minimal (no more than 25%), 32.31% feel that it covers about half, 16.43% believe the coverage is substantial (more than 75%), and 5.23% think it is fully covered. This suggests that most respondents perceive the coverage of sustainable architectural design content and knowledge in their courses to be moderately low, indicating room for improvement.

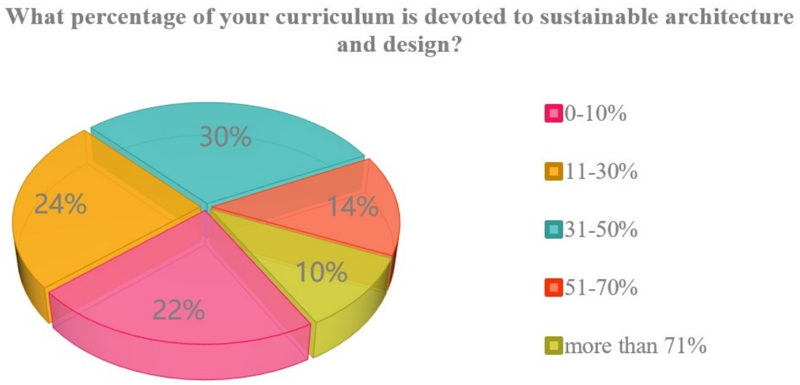

Figure 12. Percentage of content that students perceive as sustainable architecture design.

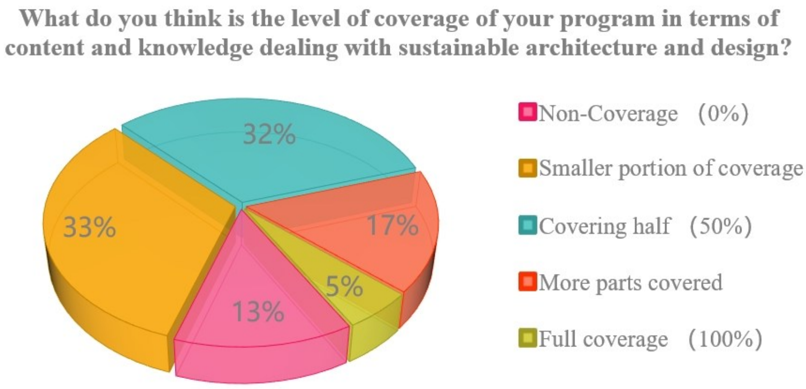

Figure 13. Proportion of students who perceive the current level of coverage of the curriculum in terms of content and knowledge related to sustainable architecture and design.

Participants generally rated the effectiveness of their specialized courses in covering sustainable architectural design content as average. In **Figure 14**, 46.39% of participants found the effectiveness to be moderately satisfactory, 23.65% rated it as fairly satisfactory, and 11.55% rated it as highly satisfactory. In contrast, only 5.78% of participants were very dissatisfied, and 12.64% expressed low satisfaction. Overall, most participants held a neutral or positive view regarding the effectiveness of their courses in teaching sustainable architectural design content.

Through **Figure 15**, we can observe that the distribution of participants' time spent learning sustainable architectural design each week is as follows: less than 1 h (27.62%), 1–3 h (23.1%), 4–6 h (24.01%), 7–9 h (10.47%), and more than 9 h

(14.8%). These data indicate that most participants spend between 1 to 6 h per week on learning sustainable architectural design, with the highest proportion (24.01%) dedicating 4–6 h. A smaller group of participants (14.8%) spends more than 9 h per week on this subject.

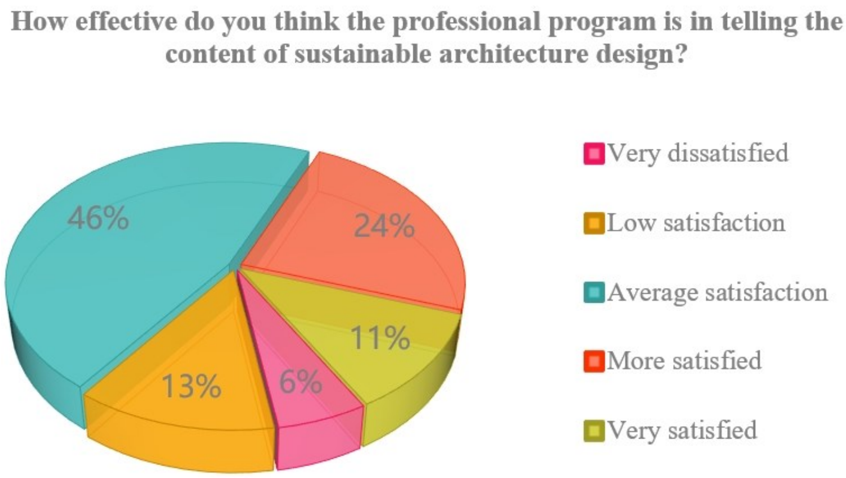

Figure 14. Percentage of students who think current professional programs are effective in telling the content of sustainable architecture design.

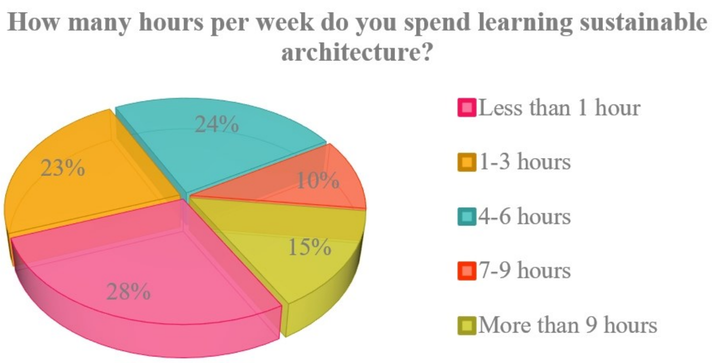

Figure 15. Number of hours per week students spend learning about sustainable architecture design.

Regarding the availability of practical projects or studio practices related to sustainable architecture, 41.88% of respondents indicated "yes", while 58.12% indicated "no". Thus, the majority of courses do not offer practical projects or studio practices in sustainable architecture. This situation suggests that although students generally recognize the importance of sustainable architectural design and their courses include some relevant content, there remains a significant deficiency in practical opportunities.

To address this issue, educational institutions should increase the number of practical projects available, providing more hands-on opportunities for students to better understand and apply the principles and techniques of sustainable architectural design. Institutions can not only enhance students' practical skills but also deepen their understanding of theoretical knowledge, thereby comprehensively improving their overall competence in the field of sustainable design.

7. Conclusion

This study examines students' understanding of Sustainable Building Design Concepts (SBDC), current curriculum design, and teaching effectiveness. The findings reveal significant disparities in students' mastery of SBDC, with 45.85% of respondents having a basic understanding and 29.96% having a weaker understanding. Over 70% of respondents consider SBDC "very important" or "important" in architecture, with 25.45% rating it as "very important." This reflects a strong societal emphasis on sustainable development. Additionally, 53.89% of respondents reported that over 30% of their course content involves SBDC, with 29.78% indicating that this proportion is between 31%–50%.

The study shows that students' understanding of SBDC improves significantly with academic progression and practical experience. Senior students and those involved in practical projects demonstrate better comprehension and application of SBDC. This underscores the importance of hands-on practice in enhancing students' grasp of SBDC. The findings suggest a need for improving course content and teaching effectiveness, particularly by increasing SBDC content in lower-year courses and incorporating more practical projects to enhance students' practical skills.

Most students recognize the importance of SBDC, with over 70% considering it "very important" or "important" in architecture. This suggests that current education efforts have been somewhat effective in conveying the significance of SBDC. However, more than half of the respondents believe that SBDC content constitutes over 30% of their courses. Despite this, there is a need to improve teaching effectiveness, especially in lower-year courses, where more SBDC content and practical projects should be introduced to improve students' application abilities and satisfaction.

The results indicate significant disparities in students' understanding of SBDC and highlight the crucial role of practical experience in enhancing understanding. The research confirms the initial hypotheses that academic progression and practical experience significantly impact SBDC understanding. Additionally, the proportion of SBDC content in the curriculum is positively correlated with student satisfaction and understanding levels. To improve SBDC education, it is recommended to increase the proportion of SBDC content in courses, particularly at lower academic levels, and to enhance practical components in the curriculum. These measures can improve students' understanding and application of SBDC, contributing to addressing climate change and promoting sustainable development in the construction industry.

The study's findings have significant implications for policy-making, professional practice, and future research. Policymakers should promote educational reforms by increasing SBDC course content and practical components and optimizing resource allocation to ensure high-quality educational coverage. In professional practice, architectural firms should enhance training for newly hired architects to improve their SBDC skills. Future research should expand the sample size, adopt longitudinal designs, and employ diverse data collection methods to further validate and extend the study's findings.

8. Limitation and future work

This study has several limitations and constraints that may affect the interpretation and generalizability of the results. First, despite the relatively large sample size, selection bias may exist. If the sample is primarily concentrated in certain regions or universities, the vast geographic diversity and the large number of schools in China may mean the results do not fully represent all architecture-related students nationwide, thus limiting the generalizability of the findings. Second, the study relies heavily on self-reported data from respondents, which may introduce response bias and social desirability effects, potentially overestimating or underestimating the actual situation and affecting the accuracy of the results. Finally, the design of the questionnaire may have limitations, failing to encompass all factors influencing students' understanding and learning outcomes of SBDC. The interpretation of the questions may also vary among respondents, impacting the validity and reliability of the data.

Future research can be expanded in several areas to further deepen the understanding of Sustainable Building Design Concepts (SBDC) education and improve teaching practices. First, it is recommended to conduct large-scale nationwide surveys covering more regions and universities to ensure sample diversity and representativeness, thereby enhancing the generalizability of the results and revealing differences and commonalities in SBDC education across different regions and universities. Second, longitudinal studies should be conducted to track the changes in SBDC understanding and learning outcomes among the same cohort of students at different academic stages. Long-term data collection would reveal causal relationships and clarify the direct impact of academic progression and practical experience on SBDC understanding, providing more robust empirical evidence. Additionally, international comparative studies on SBDC education in collaboration with universities from other countries or regions can be conducted. By learning from successful experiences and best practices, an international perspective can help identify the strengths and weaknesses of different educational systems in SBDC education, providing references for educational reform in China. Lastly, research on the specific effects of different policy measures (such as funding, accreditation, and scholarships) on the promotion of SBDC education should be undertaken. Evaluating the effectiveness of policy interventions can lead to more precise and effective policy recommendations, promoting the widespread implementation and continuous improvement of SBDC education.

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Appendix

Questionnaire（Students） 调查问卷（学生）

Integration of sustainable architecture design theory in Chinese architecture curriculum and practice
可持续建筑设计理论在中国建筑学专业课程和实践中的整合

Part I: Information

第一部分：信息

Name 姓名： ______________________
University 所在大学： ______________________
Grade 年级： ______________________
Subject 专业：

☐ Architectural Design 建筑设计
☐ Urban Planning 城市规划
☐ Landscape Design 景观设计
☐ Other (specify) 其他（请说明）： ______________________

Have you participated in an internship or research project related to sustainable architecture?
您是否有参与过与可持续建筑相关的实习或研究项目？

☐ Yes 是 ☐ No 否

Part II: Interview Questions

第二部分：采访问题

What percentage of your curriculum is devoted to sustainable architecture and design?
在您的课程中，可持续建筑设计的内容占比是多少？

☐ 1%–10% ☐ 11%–20% ☐ 21%–30% ☐ 31%–40%
☐ more than 40%（40%以上）

a. How well do you understand sustainable architecture and design?
您对可持续建筑设计的理解程度如何？

☐ 1-Little understanding 非常不了解
☐ 2-Not too much understanding 不太了解
☐ 3-Fair understanding 一般了解
☐ 4-Somewhat understanding 较为了解
☐ 5-Very much understanding 非常了解

b. What do you think is the importance of sustainable architecture design in architecture course？
您认为可持续建筑设计在建筑学中的重要性是？

☐ 1-Very low 非常低
☐ 2-Low 较低
☐ 3-Average 一般
☐ 4-Higher 较高

☐ 5-Very high 非常高

c. Does your program offer a practical project or studio practice on sustainable architecture?
您的课程是否提供了关于可持续建筑的实践项目或工作室实践？

☐ Yes 是 ☐ No 否

d. Have you participated in a competition on sustainable design?
您是否参与过关于可持续设计的竞赛？

☐ Yes 是 ☐ No 否

e. What are your expectations or suggestions for the future integration of sustainable design theory in architecture curricula and practice?
您对未来建筑课程和实践中可持续设计理论的整合有何期待或建议？

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