International Journal of Sustainability in Higher Education

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Building a resilient world: the contribution of architecture curricula to sustainable development

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Received 9 May 2025
Revised 30 September 2025
27 March 2026
Accepted 30 March 2026

Abstract

Purpose – The design of buildings and urban areas holds immense potential to shape sustainability, encompassing considerations of material usage, energy efficiency and environmental impacts throughout construction and life cycle. Architects play a pivotal role in this endeavour. In the evolving landscape of architectural education, there remains a significant gap in understanding the full scope of its potential and challenges. This study aims to explore the role of higher education institutions and explores the extent to which architecture curricula contribute to sustainable development.

Design/methodology/approach – The study used an online survey, designed around sustainability frameworks to assess how architecture curricula incorporate sustainability. It gathered 110 responses from 30 countries, with data analysed using non-parametric tests (Kruskal–Wallis and Mann–Whitney *U* test) to examine country-level differences and barriers to integrating sustainability.

Findings – The findings reveal a prevalent consideration of sustainability in curricula, with a notable emphasis on environmental dimensions, closely followed by social and economic aspects. However, challenges persist, notably the lack of sustainability training for educators and limited time allocation for integrating sustainability components into educational programmes.

Originality/value – This study's novelty lies in its comprehensive investigation into the emphasis placed on sustainability within architecture education. It offers original insights collected from diverse universities worldwide through the documentation of trends observed across 30 countries, providing valuable insights on the training landscape for architects and paving the way for informed strategies to enhance sustainability integration in architectural curricula and practice.

Keywords Architecture education, Net-zero buildings, Building operations, Circular economy, Project life cycle, Green building

Paper type Research paper

Declaration of interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

International Journal of Sustainability in Higher Education
Vol. 27 No. 10, 2026
pp. 323-343
Emerald Publishing Limited
1467-6370
DOI 10.1108/IJSHE-05-2025-0423

1. Introduction

When architecture is applied to the built environment, it is intended as the art or practice of designing and constructing human shelters, and as such, it has been fulfilling the need to protect our early ancestors and their kin from the vagaries of uncertain weather and foes since prehistoric times. Architecture and sustainable development have been interlaced along the path of human evolution since the dawn of ancient civilisations. However, in a leap of time through the most recent decades, the human population has tripled and it is expected to reach the 10 billion mark by 2050 (The World Bank, 2021). This exponential growth has been made possible by the successes achieved in agriculture and more human endeavours that enabled early human societies to settle from their itinerant lifestyle (Simon, 2019). Yet, the resources to construct the needed infrastructure to meet the needs for food storage, water and shelter have had destabilising impacts on Earth's homeostasis to levels that have been described as alarming and unsustainable. Thus, human design and its applications in architecture are not free from causing and even amplifying these impacts, while continuing to obstruct the achievement of sustainability, especially when 55% of the human population now lives in urban environments (Rockström and Gaffney, 2021).

Architects have remarkable potential to contribute to Agenda 2030, especially for those sustainable development goals (SDGs) directly connected to architecture. More specifically, SDG 7 (renewable energy), SDG 9 (innovation and infrastructure), SDG 11 (sustainable cities and communities) and SDG 4 (excellence in education), match the competence and skills that architects should acquire through the completion of their study programmes (Anthony Jnr *et al.*, 2020; Chel and Kaushik, 2018; Pons-Valladares and Nikolic, 2020). Although the remaining SDGs may seem marginal to the interests and experience needed by architects, all goals intersect with design and architecture (Pradhan *et al.*, 2017).

Current research in sustainable architecture is vibrant and inclusive of holistic strategies regarding the role of design in contributing to sustainable development (Lami and Mecca, 2021). At least four primary research foci inspire academia, such as:

(1) how architecture could contribute to developing sustainable/smart cities (Anthony Jnr *et al.*, 2020; Mahdiraji *et al.*, 2018; Silva *et al.*, 2018);

(2) sustainable design and construction (Pons-Valladares and Nikolic, 2020);

(3) the extent to which cultural aspects and vernacular architecture are connected to sustainable development (Liu *et al.*, 2019; Tawayha *et al.*, 2019); and

(4) the role of technology (e.g. Internet of Things and automation processes), that yield solutions created by urban problems such as mobility, technical infrastructure, pollution and waste management (Mahdiraji *et al.*, 2018).

In this context, increasing attention has been given to net-zero and low-carbon buildings, which aim to minimise energy consumption and greenhouse gas emissions across the building life cycle (Kashyap *et al.*, 2022; Leal Filho *et al.*, 2026; Leal Filho *et al.*, 2023d; Sartori *et al.*, 2012; United Nations Environment Programme (UNEP), 2023). These approaches highlight the importance of integrating energy performance, material efficiency and operational considerations into architectural design, reinforcing the need for corresponding competencies to be embedded within architecture curricula (Chel and Kaushik, 2018; Hashimzada *et al.*, 2026; Husnain *et al.*, 2026; Kashyap *et al.*, 2022).

All these topics have a point in common: they need sustainability-driven architects who are knowledgeable and passionate about sustainable development (Bonenberg and Kapliński, 2018). The education of architects is growing in importance either for its role in sustainable architecture research or for practical aspects aimed at guaranteeing the

well-being of people, economic prosperity and environmental protection (Oberfrancová *et al.*, 2019). Thus, there may be a need to revisit curricula in architecture to prepare professionals who will be called to assist in finding solutions to the problems that were created by the flaws of the present design (Mahdiraji *et al.*, 2018). Many argued that study programmes in architecture are by nature prone to be multidisciplinary and therefore, inclusive of education principles for sustainable development (Orr, 1992; Sterling, 2011; Borsari, 2012; Leal Filho *et al.*, 2021; Iyer-Raniga and Dalton, 2021), and supportive of the theoretical underpinnings of this assessment.

This study evaluated the status of curricula in architecture while presenting their potential and challenges for moving along a sustainability trajectory, as also demonstrated by on-campus projects and initiatives in sustainable development. Its key focus was directed at assessing architects' preparedness for adapting to new design trends that have expanded from the built environment to the biosphere to contribute effectively to sustainable development. The study contributes original knowledge by providing empirical evidence from a diverse international sample on how sustainability is currently embedded in architecture curricula. It further identifies specific gaps between the recognition of sustainability and its practical implementation, particularly in relation to the dominance of environmental dimensions and the limited integration of social, economic and life-cycle perspectives. These insights enable a more precise understanding of how architecture education can better align with sustainability goals. This study is conceptually grounded in the principles of Education for Sustainable Development, which emphasise the integration of environmental, social and economic dimensions into teaching and learning processes, as well as the development of interdisciplinary competencies required to address complex sustainability challenges (Leal Filho *et al.*, 2021; Iyer-Raniga and Dalton, 2021). This perspective provides a framework for assessing how architecture curricula incorporate sustainability and prepare future professionals to engage with sustainability transitions.

2. Architecture and campus sustainability

Universities can be viewed as fully functional cities at a smaller scale (Alrashed, 2020; Perez *et al.*, 2021) and as living laboratories (Leal Filho *et al.*, 2023c), assisting future professionals to develop skills and competence in sustainability. The latter will benefit the community, either at a local or global level, while more universities are cherishing a culture of campus sustainability with expectations that this may boost the transition to a sustainable society (Iyer-Raniga and Mori Junior, 2020; Leal Filho *et al.*, 2023a). Thus, a holistic approach to sustainable development is required, a point acknowledged by the Sustainable Development Solutions Network, arguing that the concept includes socio-political disciplines like economics, social justice and environmental management (SDSN, 2020) to which, for the purpose of this study, architecture and design were also considered. However, understanding the interdisciplinary nature of the sustainability concept is fundamental for achieving efficient use of resources and acquiring improved skills and knowledge that may contribute to implementing sustainable design principles within an academic context.

To this end, universities could re-examine internal organisations, establishing new organisational units and new educational programmes, which prioritise sustainable development and facilitate students' learning to focus on systems thinking about challenges faced in achieving long-term sustainable development strategies and goals (SDSN, 2020; Iyer-Raniga *et al.*, 2022). Thus, universities will actively engage in the education of future professionals and utilise the lessons learnt from such academic processes to create partnerships (Leal Filho *et al.*, 2024) with commerce and industry to further sustainable development research and help guide principles learnt within a broader context.

The importance of integrating concepts of sustainable development within architecture curricula continues to be understood and the success of such processes continues to be analysed (Ismail *et al.*, 2017). However, such knowledge equally entails theoretical and practical aspects (Kashyap *et al.*, 2022), and further considerations of the interconnections between teaching and operations are needed. Students' receptivity to sustainable development principles is enhanced if they are engaged through the practical implementation of sustainable strategies, so the principles are assimilated without remaining merely theoretical speculations (Donovan, 2018; Iyer-Raniga and Dalton, 2020).

Architects' training has a strong connection to the concept of smart cities, which may be focused on creating increased sustainability awareness among campus users. In this context, campus sustainability awareness will substantially foster the campus initiatives to be replicated outside the campus environment. The current literature on university campuses contains numerous examples of projects addressing teaching (Aichholzer *et al.*, 2018; Mileto *et al.*, 2015) and campus sustainability, focusing on the role of architecture in sustainability (Del Borghi *et al.*, 2021; Villegas-Ch *et al.*, 2019) and how these impact positively the surrounding society supported by the university leadership commitment towards sustainability change, either on campus or in teaching programmes (Iyer-Raniga and Mori Junior, 2020). Although small in number, unsuccessful cases, highlighted by Amaral *et al.* (2021), are reported as examples of inadequate planning, design or maintenance, low return on investment or unclear commitment to sustainable behaviour. These examples underscore the need to address the decision-making process more effectively.

3. Method

3.1 Survey design

The investigation tool for this evaluation study was a specifically constructed online survey. The survey was developed and applied internationally, aiming to investigate the contribution of curricula in architecture to sustainable development. It targeted architecture and urban planning professionals around the world at higher education institutions (HEIs), whose positions at their universities ranged from administrative to research or teaching.

The survey was designed to identify the extent to which architecture education takes sustainability and best practices at university campuses into account. The research team aimed to prepare a straightforward questionnaire to answer the research questions and facilitate data collection. The authors prepared and pre-tested the questions by six professionals and researchers with experience in architecture and sustainability-related issues in the education environment.

The proposed questions in the survey were related to the three pillars of sustainability: social, economic and environmental. They followed the sustainability criteria related to architecture that are based on categories and topics approached by the most recognised green building rating systems, namely, Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM), Comprehensive Assessment System for Built Environment Efficiency, Green Star, WELL Building Standard (WELL), Sustainable Sites Initiative (SITES) and the Living Building Challenge (Renner, 2016). Therefore, the survey was organised around seven themes:

(1) energy efficiency;
(2) water efficiency;
(3) materials selection;
(4) emissions control;
(5) user health;

(6) user well-being; and

(7) landscape.

Besides these themes, the questionnaire included a question about the 17 SDGs to substantiate whether these are considered in architecture curricula. These widely recognised systems are used because they provide standardised, research-based frameworks for assessing multiple dimensions of sustainability – energy, water, materials, indoor environmental quality and well-being. Their broad acceptance allows for consistent benchmarking, regulatory alignment and integration into professional practice and architectural education, unlike other criteria that may lack standardisation or international recognition.

The survey was sent via Google Forms to a sample of 500 researchers who are part of or associated with the Inter-University Sustainable Development Research Programme (IUSDRP). Because the respondents are familiar with the concepts of sustainability and the 2030 Agenda, their opinions can be regarded as well-informed ones in line with purposive sampling techniques. Responses were gathered between 1st November 2021 and 18th May 2022.

3.2 Sample

The data collection strategy was voluntary, because respondents received the invitation to participate and decided whether or not to respond to the survey questions. Out of 500 individuals initially contacted as part of IUSDRP, 110 responded. Given the exploratory and comparative nature of this study, the sample size is considered adequate for identifying patterns and trends across diverse international contexts rather than for statistical generalisation. In studies involving specialised populations, such as academics and professionals in architecture and sustainability, purposive sampling and moderate sample sizes are commonly used to capture informed perspectives and generate indicative insights. This approach is consistent with methodological literature indicating that exploratory survey research can provide valuable insights even with relatively modest sample sizes, particularly when the aim is to explore relationships and emerging patterns rather than to generalise findings to a wider population (Creswell and Creswell, 2018; Hair *et al.*, 2013). Therefore, the sample is appropriate for capturing a broad range of expert perspectives across different geographical and institutional contexts, in line with the exploratory objectives of the study.

The country distribution of the 110 respondents is presented in Figure 1. The sample is distributed among developed countries (Australia, Belgium, Canada, Germany, Italy, Japan, Netherlands, Portugal, Spain, Sweden, UK and USA), in transition countries (Albania, Lithuania and Serbia) and developing countries (Brazil, Cameroon, Chile, China, Colombia, India, Iran, Kenya, Malaysia, Mexico, Mozambique, Nigeria, Pakistan, Peru and Uruguay), considering the UN's classification criteria (United Nations, 2021).

All participants' roles were closely related to teaching and research within their institutions, and 64% have teaching as their primary position, followed by 28% of respondents who are in research and 8% who are used in various administrative roles. A significant part of the sample has a consolidated experience with architecture-related activities (e.g. teaching, research and operations) in a HEI (31% indicated between 10 and 20 years and 31% indicated more than 20 years of experience). The remaining respondents have between 5 and 10 years, 2–5 years or less than two years of experience (24%, 8% and 6%, respectively).

In total, 28% of participants identified as being "in research" were primarily engaged in academic activities, often alongside teaching responsibilities, contributing directly to the advancement of architectural knowledge and the integration of research into the curriculum.

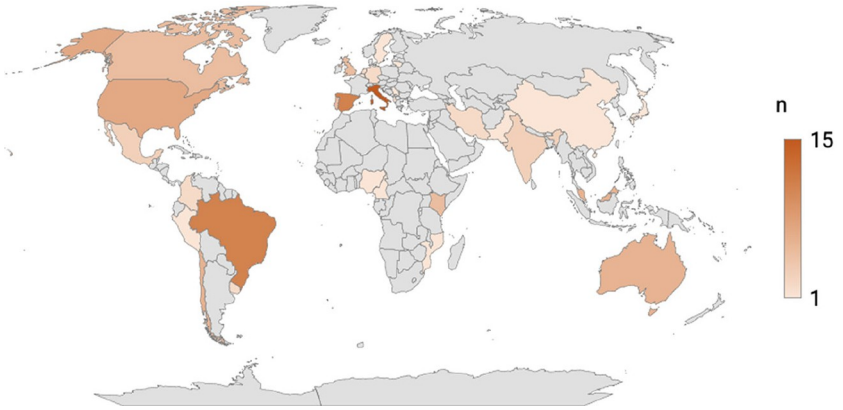

Figure 1. Map of participating countries in this survey with the number of respondents in each country

The 8% categorised under "administrative roles" included deans, directors and department heads who also held joint professorial appointments. These individuals were directly involved in curriculum development and strategic educational planning, ensuring that administrative decisions were informed by both teaching experience and research expertise. Their dual roles allowed them to bridge academic leadership with hands-on educational practice, making their perspectives highly relevant to understanding and shaping architecture curricula.

The data collection strategy was voluntary because respondents received the invitation to participate and decided whether to respond to the survey questions. As it is the standard in such research endeavours, no personal information was collected or stored and the answers to the survey questions could not be traced back to any respondent, thus ensuring respondents' anonymity. The nature of the research, the methods used and the fact that no personal data was stored or can be traced back to individuals, conforming with General Data Protection Regulation standards, means that the study is not subject to an ethics permit, as specified by the Association of Medical Ethics Committee in Germany, the body responsible for such assessments in the country leading this study.

3.3 Statistical analyses

To determine the statistical differences between the identified groups, the authors first conducted normality tests to assess whether the selected variables adhered to a normal distribution. Specifically, the Kolmogorov–Smirnov and Shapiro–Wilk tests were used. Given that the data did not follow a normal distribution ($p = 0.05$), non-parametric tests were subsequently performed (Hair *et al.*, 2013).

For the non-parametric analyses, two primary tests were utilised. The Kruskal–Wallis test was applied to evaluate hypotheses across three groups (developed economies, developing economies and economies in transition). In addition, the independent-samples Mann–Whitney *U* test was used (Hair *et al.*, 2013) to analyse binary categories of barriers (presence or absence): lack of interest from students, lack of interest from instructors, lack of sustainability training for instructors, lack of support from university administration and limited amount of time. The results can be seen in Section 4.2.

4. Results

4.1 Quantitative analysis of the survey results

The results of the survey show that the education programmes of the respondents keep sustainability in high consideration, in alignment with the views of previously referenced authors (Lami and Mecca, 2021; Mahdiraji *et al.*, 2018; Leal Filho *et al.*, 2023b). Over one-third of the sample (35%) indicated the best scenario possible "to a very great extent", followed by 19% specifying "to a great extent" and 27% "to a moderate extent". "To a little extent" was expressed by 17% of the sample, and "not at all" was reported by only one respondent (1%).

As illustrated in Figure 2, of all sustainability dimensions, the environmental one seems to be more widely covered in the respondents' architecture curricula with "great extent" and "very great extent" (77%), whereas these values in social and economic dimensions represented 55% and 39%, respectively. These responses agree with the close relationship between sustainable development and architecture curricula as pointed out by Boarin *et al.* (2020).

When asked to report on the spatial scale considered when sustainability is taught, architecture (buildings) and urban design were indicated by a major part of the study sample (80.9% and 70%, respectively). Urban planning was present in almost half of the respondents' programmes (44.5%), and landscape and land-use planning were aspects covered in approximately one-third of the programmes (Figure 3).

Regarding the sustainability-related aspects in the respondents' architecture education programmes, sustainable design and energy efficiency occupied important positions in the list of investigated options (79.1% and 76.4% of all respondents). The least mentioned point was emissions control, with 30% of responses. Other elements referred to by the respondents included: carbon footprint, net-zero carbon design, resilience, sustainable resources and environmental life-cycle assessment (Figure 4).

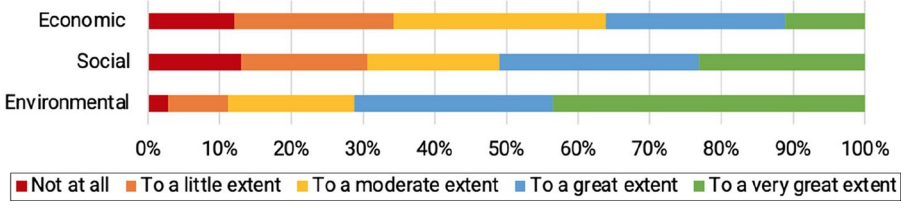

Figure 2. Extent to which sustainability is considered in the architecture curricula

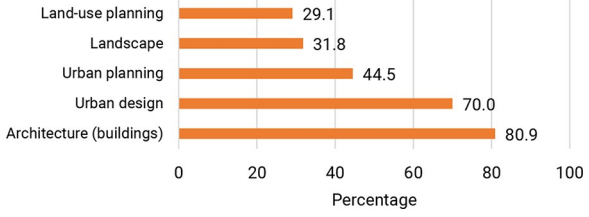

Figure 3. Spatial scale considered in architecture education

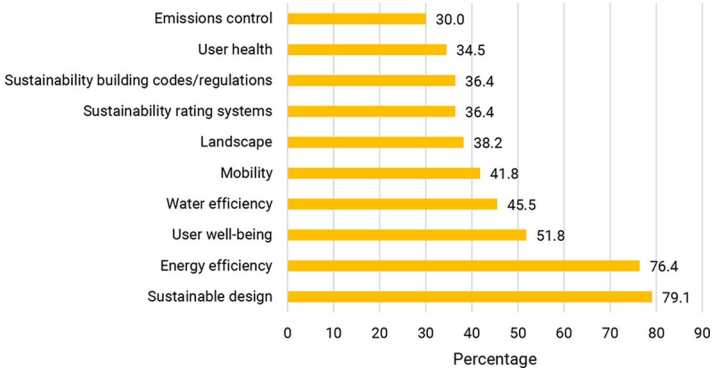

Figure 4. Sustainability-related aspects covered in architecture education

The concept design was the stage of the project life cycle in which sustainable principles were mostly applied in the respondents' architecture education programmes (81.8%). The least deemed stage was the operation, reported by only 33.6% of the subjects (Figure 5).

Lack of sustainability training to instructors and a limited amount of time were the most common challenges reported by respondents to the inclusion of sustainability components in architecture education with 58.2% and 53.6%, respectively. Lack of interest from students was noted by less than 10% of the respondents' sample (Figure 6).

Other issues highlighted were sustainability not being connected to the respondents' disciplines; limited amount of financial resources; lack of interest by educators; difficulty in getting out of disciplinary silos for interdisciplinary education; and demands on student time.

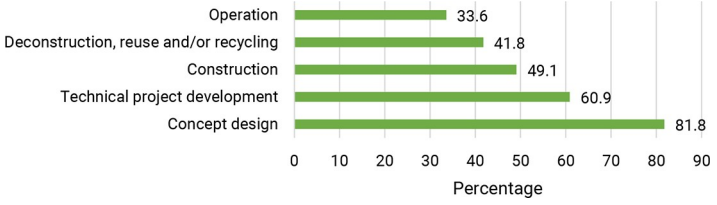

Figure 5. Stages of the project life cycle when sustainability is considered

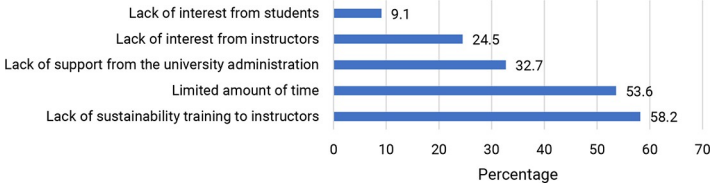

Figure 6. Challenges to include sustainability components in architecture education

Most respondents (68%) indicated that the future inclusion of sustainability components in their architecture education is likely to increase and be more widely used. Only 5% of the subjects suggested such inclusion may decrease, while 27% thought it would remain the same as it currently is.

A practical approach in the curricula was reinforced by several studies developed by Boarin *et al.* (2020), Grover *et al.* (2020) and Oberfrancová *et al.* (2019). The preparation for the future also connects with the findings of Mahdiraji *et al.* (2018) and contributes to the society transition and the paradigm shift proposed by SDSN (2020).

Regarding sustainability rating systems and sustainability-related building codes/regulations, LEED was selected as the most reported system taught in architecture education programmes (44.5%). Among the survey options, the Living Building Challenge was indicated by 12.7% of the subjects, followed by WELL (10%) and SITES (6.4%). BREEAM and PROCEL were also mentioned by some respondents (7% and 4%, respectively), among other local/national regulations such as the German Sustainable Building Council, Australian Green Star and Malaysia Green Building Index.

Figure 7 shows the extent to which each SDG is linked to sustainability teaching in the respondents' architecture education programme. Only three SDGs had over 50% of responses combining the best two categories ("great" and "very great" extent): SDG 7 (55%), SDG 11 (63%) and SDG 13 (63%). On the other hand, eight SDGs gathered 50% of answers encompassing the worst categories ("not at all" and "to a little extent"): SDG 1 (69%), SDG 2 (74%), SDG 8 (55%), SDG 10 (52%), SDG 14 (65%), SDG 15 (52%), SDG 16 (67%) and SDG 17 (59%).

4.2 Hypotheses testing: Challenges and barriers

The Kruskal–Wallis test is a non-parametric statistical test used to determine if there are significant differences between the distributions of a variable across multiple groups. It is an extension of the Mann–Whitney *U* test to more than two groups and is used when the assumptions of one-way ANOVA (i.e. normal distribution of the data and homogeneity of variances) are not met. Table 1 presents a summary of all tests performed as part of this investigation.

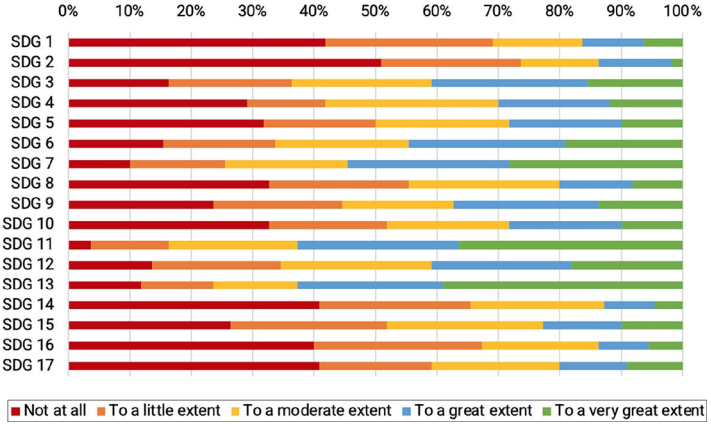

Figure 7. SDGs in the architecture teaching practice

Table 1. Hypothesis test summary: (a) the significance level is 0.050 and (b) asymptotic significance is displayed

Dimension	Null hypothesis	Sig.(a) and (b)	Decision (reject or retain the null hypothesis)
Country	The distribution of sustainability consideration in architecture education is the same across countries	0.03	Reject
	The distribution of social sustainability consideration in architecture education is the same across countries	0.319	Retain
	The distribution of economic sustainability consideration in architecture education is the same across countries	0.396	Retain
	The distribution of environmental sustainability consideration in architecture education is the same across countries	0.07	Retain
Lack of student interest	The distribution of sustainability consideration in architecture education is the same across categories of barriers	0.965	Retain
	The distribution of social sustainability consideration in architecture education is the same across categories of barriers	0.012	Reject
	The distribution of economic sustainability consideration in architecture education is the same across categories of barriers	0.177	Retain
	The distribution of environmental sustainability consideration in architecture education is the same across categories of barriers	0.627	Retain
Lack of interest from instructors	The distribution of sustainability consideration in architecture education is the same across categories of barriers	0.024	Reject
	The distribution of social sustainability consideration in architecture education is the same across categories of barriers	0.383	Retain
	The distribution of economic sustainability consideration in architecture education is the same across categories of barriers	0.078	Retain
	The distribution of environmental sustainability consideration in architecture education is the same across categories of barriers	0.394	Retain
Lack of sustainability training for instructors	The distribution of sustainability consideration is the same across categories of barriers	0.004	Reject
	The distribution of social sustainability consideration is the same across categories of barriers	0.032	Reject
	The distribution of economic sustainability consideration is the same across categories of barriers	0.170	Retain
	The distribution of environmental sustainability consideration is the same across categories of barriers	0.079	Retain

(*continued*)

Table 1. Continued

Dimension	Null hypothesis	Sig.(a) and (b)	Decision (reject or retain the null hypothesis)
Lack of support from university administration	The distribution of sustainability consideration is the same across categories of barriers	0.016	Reject
	The distribution of social sustainability consideration is the same across categories of barriers	0.151	Retain
	The distribution of economic sustainability consideration is the same across categories of barriers	0.595	Retain
	The distribution of environmental sustainability consideration is the same across categories of barriers	0.034	Reject
Amount of time	The distribution of sustainability consideration is the same across categories of barriers	0.110	Retain
	The distribution of social sustainability consideration is the same across categories of barriers	0.951	Retain
	The distribution of economic sustainability consideration is the same across categories of barriers	0.517	Retain
	The distribution of environmental sustainability consideration is the same across categories of barriers	0.834	Retain

The Kruskal–Wallis test results indicate that there is a significant difference in the extent to which sustainability is considered in architecture education programmes across different country classifications ($p = 0.03$). This suggests that country classification affects how sustainability is integrated into these programmes. However, for the dimensions of sustainability examined in the architecture design education programmes, no significant differences were found across country classifications ($p = 0.319$, 0.396 and 0.07, respectively). This implies that these dimensions are uniformly addressed across different countries, regardless of their classification.

Because the Mann–Whitney *U* test is appropriate for assessing differences between two independent groups when parametric test assumptions, like normality, are not met, it was used to evaluate the effect of student interest on the integration of sustainability in architectural education. This non-parametric test is appropriate for assessing the degree of sustainability consideration in the curriculum across different student interest levels because it is especially helpful for analysing data that is ordinal or non-normally distributed.

The results from the Mann–Whitney *U* test reveal that student interest does not significantly affect the overall inclusion of sustainability in the architecture curriculum ($p = 0.965$). This suggests that the degree to which sustainability is incorporated into the curriculum depends on the degree of student interest. A significant difference ($p = 0.012$) is shown; nevertheless, when concentrating only on the social aspect of sustainability, indicating that a decrease in student interest is correlated with a lower priority on social sustainability issues. On the other hand, there are no significant variations observed in the economic ($p = 0.177$) and environmental ($p = 0.627$) dimensions, suggesting that these elements are consistently incorporated irrespective of the interest levels of students. The importance of student engagement in creating sustainability education can be seen by the observation that, while student interest greatly influences its emphasis on social sustainability, it has no major impact on the integration of economic and environmental sustainability parts.

Based on the degree of institutional interest, the test reveals a significant difference ($p = 0.024$) in the amount of sustainability considered in the curriculum. This indicates that the entire integration of sustainability into the programmes is significantly affected by the institutions' lack of interest. Based on institutional interest, there is no statistically significant difference for the social dimension of sustainability ($p = 0.383$). This suggests that the incorporation of social sustainability subjects in the curriculum is not greatly impacted by the interest level of institutions.

The test for the economic dimension of sustainability also shows no significant difference ($p = 0.078$) related to institutional interest. Although this result is closer to the threshold, it still suggests that institutional interest does not significantly influence the integration of economic sustainability topics. Similarly, the environmental dimension shows no significant difference ($p = 0.394$) based on institutional interest. This means that environmental sustainability topics are included at a consistent rate, regardless of institutional interest levels.

While the overall consideration of sustainability in architecture education is significantly impacted by institutional interest, the specific sustainability dimensions are not significantly affected by this factor.

The results highlight the impact of a lack of sustainability training for instructors on the inclusion of sustainability in architecture education programmes. The first test shows a significant difference ($p = 0.004$), indicating that insufficient training for instructors significantly affects how much sustainability is considered in the curriculum. Similarly, for the social dimension of sustainability, a significant difference ($p = 0.032$) is observed,

suggesting that the lack of instructor training impacts the inclusion of social sustainability topics. On the other hand, the environmental ($p = 0.079$) and economic ($p = 0.170$) dimensions show no significant differences. This shows that instructors' lack of sustainability training does not greatly affect how these elements are integrated. Overall, while the general consideration of sustainability and the social dimension are significantly impacted by instructor training, the economic and environmental dimensions are consistently included regardless of the training level.

The test results show that the overall consideration of sustainability in architecture education is significantly affected ($p = 0.016$) by a lack of support from university administration. Which means that integrating sustainability into the curriculum requires administrative support. The inclusion of social ($p = 0.151$) and economic ($p = 0.595$) sustainability characteristics across different administrative support levels, however, did not differ significantly. A significant difference was found for the environmental dimension ($p = 0.034$), indicating that the integration of environmental sustainability is impacted by administrative support. Therefore, administrative assistance is essential for the integration of environmental and overall sustainability, but it has little effect on the social and economic factors.

The hypothesis test results show that time constraints do not significantly affect the inclusion of sustainability in architecture education. The Mann–Whitney *U* test reveals no significant differences in how sustainability is considered overall ($p = 0.11$) or in the specific dimensions of social ($p = 0.951$), economic ($p = 0.517$) and environmental ($p = 0.834$) sustainability. This indicates that limited time does not notably impact the extent to which these sustainability aspects are incorporated into the curriculum. While time limitations are recognised as a challenge, they do not appear to significantly influence the depth or breadth of sustainability coverage in architecture education programmes. Other factors may play a more substantial role in shaping how sustainability is integrated into the curriculum.

5. Discussion

The survey indicated that most respondents consider sustainability in their curricula with a dominating emphasis on the environmental dimensions, followed by social and economic ones, which is consistent with the proliferation of sustainability building rating systems mostly geared to environmental issues (Diaz-Sarachaga *et al.*, 2018) and the role played by buildings to reduce the impacts of climate change (Kashyap *et al.*, 2022). Architecture (80.9%) and urban design (70%) topics dominated the spatial scales for sustainability teaching across the educational institutions and were followed by landscape (31.8%) and land-use (29.1%) topics. When reporting on parts of the education programmes as the main focus, most participants favoured sustainable design (79.1%) and energy efficiency (76.4%), as also stated by Pons-Valladares and Nikolic (2020).

Sustainability rating systems and sustainability building codes and regulations stood at equal standing (36.4%), while emissions control had the least priority focus (30%). This finding is again, in keeping with the nature of the architecture disciplines that focus on design (Pons-Valladares and Nikolic, 2020). Among the sustainability rating systems favoured, LEED appeared to be most dominant, but this may have also been due to the nature of the use of LEED-derived rating systems across the surveyed countries (Diaz-Sarachaga *et al.*, 2018). Across the life cycle of projects, the emphasis was on concept design (nearly 82%) of the responses and the least focus was on building operation (33.6%). This was not surprising given the nature of the architecture programmes' dominant focus on building design rather than operations (Lami and Mecca, 2021).

The oldest rating systems, BREEAM and LEED, have existed for only about three decades (Sánchez Cordero *et al.*, 2019), meaning that an entire generation of design practitioners has not yet been fully exposed to the rating systems currently in use. In many parts of the world, such systems are even newer, creating a gap between professional design practices that respond to rating requirements and the educational curricula that prepare future architects. Student interest in sustainable design often reflects their broader awareness, shaped by local, national and international media coverage.

The predominance of the environmental dimension in architectural education can be attributed to both historical and institutional factors. Since the early 1990s, rating systems such as BREEAM and LEED have emphasised energy performance, emissions and material efficiency, thereby influencing both design education and professional expectations (Diaz-Sarachaga *et al.*, 2018). This emphasis has reinforced an environmental bias, as outcomes related to energy and carbon are easier to measure than the more complex social or economic aspects of sustainability. Architectural pedagogy also tends to frame the building primarily as a technical artefact, privileging quantifiable environmental targets over issues such as social justice or equity (Liu *et al.*, 2019; Tawayha *et al.*, 2019). In contrast, the social and economic dimensions are less tangible and often addressed by other disciplines, which makes their integration into design studios more difficult (Pradhan *et al.*, 2017). These disciplinary boundaries help explain why schools of architecture continue to foreground environmental concerns, while social and economic issues remain less visible in the curriculum.

When reporting on challenges for including sustainability into the architecture educational programmes, more than half of the participants (58.2%) reported lack of sustainability training as being the major issue, while lack of student interest stood at less than 10% (9.1%). This may be explained as the educators themselves would not have been exposed to sustainability knowledge in their own education and would have had to pick up this additional knowledge through the practice of the profession and the changing needs of the profession to respond to sustainability challenges of our time (Bonenberg and Kapliński, 2018). This is dependent on the existence of the various rating schemes and the educators' exposure to these outside teaching environments.

Figure 7 shows that the integration of the SDGs into architectural teaching practice is only partially achieved, reflecting a lack of coherence and operationalisation across coursework and curricula. These findings point to the need for a redesign of architecture programmes that more effectively integrate the well-established theoretical framework of Education for Sustainability with the teaching and learning process.

More than half the participants also indicated time as being an issue (53.6%) to include sustainability considerations in the curriculum. This finding aligns with the dominant focus across art and aesthetics, design and social sciences disciplines underpinning architecture programmes (Liu *et al.*, 2019; Tawayha *et al.*, 2019). Most of the survey participants indicated that in the future, sustainability aspects were likely to increase (68%) in their educational programmes. As knowledge and awareness of the impact and importance of sustainability come to the fore, inclusion in education will follow. Of the SDGs that were dominantly featured in the architecture teaching programmes, it was not surprising to note that SDG 7 on clean energy (55%), SDG 11 on cities and human settlements (63%) and SDG 13 (63%) on climate change came out on top as these respond to the core of architecture, as a discipline according to Oberfrancová *et al.* (2019).

Most respondents indicated that a sustainability plan has been implemented on their campuses (57.3%). Developed countries dominated these responses while the negative responses were exclusively observed in countries from Africa, Asia, Eastern Europe and Latin America. This is supported by general awareness and knowledge of the current state of

play of education and professional responses concerning sustainability outputs and outcomes in the cities of developed and developing countries. This also explains why sustainability certification was not uniformly considered across all respondents; with only a small proportion (20%) acknowledging the use of any certification systems for buildings on their campuses (Diaz-Sarachaga and Longo Sarachaga, 2024).

In response to the potential links between a sustainable campus and the performance of staff and students, more than half the participants considered that there is no connection or frameworks available to assess the causal links between performance and sustainable spaces, which was already addressed by Amaral *et al.* (2021). Among the strategies used to understand these links was the existence of living laboratories by a modest proportion (32%) of the respondents (Leal Filho *et al.*, 2023c). In line with the current literature, the performance of users in green buildings is an area that has yet to be mainstreamed and is an area for future study and research.

The paper shows a trend towards an educational transformation from aesthetics-oriented studios to systems-based curricula. Architectural education needs to include items such as ecological literacy, circular economy and participatory design approach, building graduates who consider themselves caretakers of socio-ecological systems rather than mere form-makers. Professionally, this suggests that architects need to widen their service providers' role and collaborate into interdisciplinary fields. In policy, the results highlight that architecture teaching needs to evolve from knowledge dissemination, on building codes and urban regulations to regenerative approaches to building design. The teaching should also encourage nature-based solutions, decarbonisation and social equity, acknowledging architectural curricula as strategic levers for the realisation of national and global sustainable development commitments.

The implications discussed below are derived directly from the empirical patterns identified in the survey results. The results from this paper lead to practical recommendations that directly reflect the gaps identified in the analysis. The strong emphasis on design stages, contrasted with the limited attention to building operation, indicates the need to expand curricula to address the full life cycle of buildings. Similarly, the predominance of environmental dimensions over social and economic aspects highlights the importance of integrating these dimensions more systematically into architectural education. In response to these findings, curricula should be revisited to include transdisciplinary approaches, with courses co-taught by experts from fields such as ecology, sociology and engineering, ensuring that sustainability is embedded as a core principle across all design processes. Furthermore, the results support the establishment of formal "living lab" collaborations, enabling students to engage with real-world sustainability challenges and apply theoretical knowledge in practice. Finally, the findings point to the need for accreditation frameworks that explicitly incorporate climate resilience, circular economy competencies and ethical engagement as key components of architectural training.

Another key implication of these findings concerns how architecture schools can strengthen their response to sustainability challenges. Professional development programmes for academic staff are essential, as they can help close the gaps in sustainability literacy identified among instructors (Ismail *et al.*, 2017). Such training would enable educators to embed not only environmental aspects but also social and economic dimensions into design curricula. In addition, interfaculty collaboration offers valuable opportunities to broaden architectural education by drawing on expertise from engineering, social sciences and environmental studies, thereby fostering systems thinking and holistic design approaches (Leal Filho *et al.*, 2021). Finally, policy incentives from accrediting bodies and professional associations can further encourage institutions to integrate sustainability more comprehensively into their programmes.

6. Conclusions

While design remains a crucial aspect of architectural education, it is imperative to recognise the broader implications of building operations for sustainability. This study provides insights into the educational priorities of architecture programmes, highlighting a predominant focus on design within curricula. As demonstrated, building management significantly influences sustainability outcomes, including energy consumption, carbon emissions and opportunities for circular economy practices. One key implication is the need for a more comprehensive approach to sustainability in the training of architects. While sustainable design principles are well integrated, there remains a notable gap in addressing building operation and life-cycle stages, which account for a substantial share of resource use. Expanding the educational focus to encompass the full building life cycle, including maintenance, operation and end-of-life considerations, would enable architects to contribute more effectively to sustainability goals, with circular economy principles offering a valuable framework to support this transition.

6.1 Key findings and implications

The findings underscore the importance of aligning architecture education with broader sustainability goals, integrating the environmental, economic and social dimensions. While environmental sustainability receives significant emphasis within curricula, there is a need to elevate attention to the economic and social aspects of sustainability. This holistic approach ensures that architects are equipped to address multifaceted challenges and contribute meaningfully to sustainable development.

The findings also highlight variability in the implementation of sustainability strategies across institutions and regions. In particular, the uneven adoption of sustainability plans and certification systems reflects differing levels of institutional commitment, indicating the need for stronger coordination and collaboration to advance sustainable practices in higher education.

Bridging the gap between educational priorities and real-world sustainability challenges requires greater integration of practice-oriented learning approaches. In particular, the use of living laboratories can provide opportunities for students and faculty to engage with the performance of sustainable spaces and better understand their real-world impacts. These findings highlight the need to further align architecture programmes with applied sustainability practices.

In terms of curricular aspects, this study highlights the need for architecture curricula to move beyond separate technical modules. A new approach is necessary, one that incorporates sustainability principles as a central focus throughout the entire education journey, from design studios to history and theory courses. This requires shifting from adding more content to integrating teaching methods that encourage systems thinking and ethical responsibility.

Three key priorities emerge for integrating sustainability into architecture education. Firstly, curricula should move beyond isolated technical modules and embed sustainability principles across all subjects. Secondly, a gap persists between intended learning outcomes and actual implementation, often due to institutional barriers such as overloaded curricula and limited faculty training. Thirdly, education programmes should strengthen the link between theory and practice through interdisciplinary, project-based learning. This approach equips graduates with both the knowledge and practical competencies required to contribute effectively to sustainable development.

6.2 Limitations and future prospects

This study has several limitations. Firstly, the empirical data were collected over a relatively short period, which may limit the temporal robustness of the findings. Secondly, the sample size ($n = 110$), while adequate for exploratory analysis, does not allow for statistical generalisation and may have influenced the identification of significant relationships. A further limitation relates to the use of a purposive sample drawn from IUSDRP participants, who are likely to be more engaged with sustainability issues, potentially introducing a positive bias in the responses. In addition, some inconsistencies were observed between descriptive findings and hypothesis testing (e.g. regarding time as a barrier), which may reflect sample-related constraints or differences in interpretation.

There is also an unresolved contradiction between reported educational barriers and statistical findings. Educators point out significant obstacles like overloaded curricula and a lack of resources. However, statistical analyses often show positive outcomes from sustainability integration. This dissonance suggests that the quantitative data may not fully reflect the qualitative challenges of implementation. As a result, the study's ability to propose effective and practical strategies is limited.

Nonetheless, the study provides an exploration into an area that has not had much research attention, and therefore, a welcome contribution to the literature because it has analysed and documented trends from 30 countries globally. This makes this study one of the most comprehensive ones on the topic. The geographical distribution of the sample offers a rough profile of how sustainability is handled at programmes in architecture, across various continents, hence helping to foster a broader understanding of the international implications of this important topic.

Future studies may also explore this topic, and qualitative methods such as content analysis may be used to assess how sustainability-related themes are embedded in course objectives and teaching practices. This would enable universities to use their campuses to support sustainability outcomes while also strengthening the professional development of educators in teaching and learning processes.

Ethics statement

The nature of the research, the methods used and the fact that no personal data was stored or can be traced back to individuals, conforming with General Data Protection Regulation (GDPR) standards, means that the study is not subject to an ethics permit, as specified by the Association of Medical Ethics Committee in Germany, the body responsible for such assessments in the country leading this study. In any case, and considering any argument requesting waiving consent, all respondents willingly agreed to participate in the study, confirmed through an additional question added to the beginning of the questionnaire, presenting options for yes or no.

Data availability

Data will be made available on reasonable request.

Acknowledgements

This paper is part of the "100 papers to accelerate the implementation of the UN Sustainable Development Goals" initiative. This work acknowledges the support of the Foundation for Science and Technology (FCT), within the framework of the UID/04292/2025, Marine and Environmental Sciences Centre (MARE).

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