

Article

Integrating Circular Economy Principles into Architectural Design Pedagogy

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Abstract

Architectural education has increasingly engaged with the Circular Economy (CE); however, integration remains largely material-centric, emphasising life-cycle accounting, efficiency, and design for disassembly, while social, cultural, and governance dimensions are under-represented. This study introduces the Circular Commons Framework, which repositions circularity as a collective, participatory, and socio-spatial practice. Using a qualitative comparative case study methodology, five international cases were analysed through eight dimensions spanning technical CE strategies and pedagogical approaches. Cross-case synthesis reveals convergent patterns around multi-scalar systems thinking, transdisciplinary collaboration, and stakeholder engagement. Nonetheless, persistent gaps emerged across cases, including those related to elective-based delivery, weak assessment infrastructure, and underdeveloped social equity dimensions. The Circular Commons Framework comprises four empirically grounded components: Circular Design Practices, Local Knowledge and Cultural Practices, Collaborative Governance, and Circular Synergy Workshops. Operationalisation guidance addresses curricular design, pedagogical methods, assessment mechanisms, and institutional enablers. Mainstreaming the framework requires systemic institutional support, including accreditation reform, supportive policy environments, and effective resource allocation, which are currently constraining even well-designed pedagogical initiatives. The framework positions architects as equity-minded stewards facilitating socially just and culturally resonant circular transitions. Limitations, including scalability tensions, indicate that the framework requires validation through longitudinal research and deeper engagement with non-Western knowledge systems.

Keywords: circular economy; circular commons; architectural design pedagogy; architectural education



Academic Editor: Chunlu Liu

Received: 12 September 2025

Revised: 7 October 2025

Accepted: 13 October 2025

Published: 21 October 2025

Citation: Patil, M.P.; Butt, A.N.; Rigoni, C.; Salama, A.M. Integrating Circular Economy Principles into Architectural Design Pedagogy. *Sustainability* **2025**, *17*, 9330. <https://doi.org/10.3390/su17209330>

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1. Introduction

Over the past decade, the Circular Economy (CE) has gained prominence in architectural discourse. However, its integration into design education remains focused mainly on material aspects, such as life-cycle analysis and design for disassembly. This narrow approach risks neglecting the social, cultural, and collective dimensions essential for meaningful transformation in the built environment. This study examines five international cases and argues for a shift toward a Circular Commons Framework. This framework sees circularity not only as material strategies but also as a collective, participatory, and socio-spatial practice that reconnects design education to communities and shared resources.

The scale of the sustainability challenge, a global crisis of balance, environmental and social interdependencies, underscores the urgency of this reorientation. Globally, the built environment generates approximately 40% of total waste, a figure that rises to 62% in the UK, where construction, demolition, and excavation account for the majority of waste streams [1,2]. This places architecture and construction at the centre of wider ecological crises, from climate change to biodiversity loss, while accelerating the depletion of finite resources [3]. Professional and institutional responses have sought to address these issues: the RIBA 2030 Climate Challenge, coupled with climate emergency declarations by numerous schools of architecture, has intensified curricular focus on carbon reduction, energy performance, and material optimisation [1]. However, these technical efforts have so far fallen short of integrating the deeper challenges of social sustainability, cultural relevance, and spatial justice arising from the lived experiences of architectural practice and urban inhabitation [4,5].

Traditional architectural education (studio-centric pedagogy) and practice have functioned mainly within a linear economic framework, where materials are extracted, transformed, and ultimately disposed of at the end of a building's lifecycle [6–8]. Yet, prevailing CE approaches in architecture remain essentially material-centric, emphasising technical efficiencies, such as design for disassembly, material passports, and adaptive reuse—without sufficiently engaging the socio-cultural, ethical, and community-driven aspects essential to equitable and resilient urban transformation. This technical bias risks reproducing existing inequalities: Who governs circular resources? Whose labour enables material recovery? Which communities benefit versus bear environmental burdens? These questions of social justice, cultural agency, and power distribution remain peripheral in CE pedagogy, which is often focused on lifecycle accounting and resource efficiency [1,4].

CE challenges this structure by proposing a circular model, in which materials and resources are refused, reduced, reused, recycled, and regenerated through iterative cycles. Yet, the prevailing CE approaches in architecture essentially centre on technical and material efficiencies, designing for disassembly, tracking materials through passports, and facilitating adaptive reuse, without sufficiently engaging the socio-cultural, ethical, and community-driven aspects essential to resilient urban transformation [1,4].

Context and Problem Statement

Current integrations of circular economy (CE) into architectural education often privilege material optimisation over the broader context of spatial practice, social justice, and local community empowerment [3,4]. For example, CE is frequently presented as a set of technical disciplines, material passporting, recycling technologies, and energy minimisation rather than as a holistic and collaborative design process [1,9]. Assessment frameworks and pedagogical interventions also remain focused on quantitative indicators, such as material circularity and carbon footprints, while neglecting qualitative dimensions, including place-making, agency, and shared stewardship [10]. As a result, early-stage architectural students often develop competencies that enable them to minimise waste and optimise resources, without cultivating the critical frameworks necessary to address access, participation, or equitable governance in the spaces they design [2].

Practitioners, educators, and students widely acknowledge this gap. Swedish research has shown that despite strong curricular references to sustainability, circular economy topics, especially those relating to social responsibility and systems thinking, remain marginal in most architecture programmes, and graduates themselves report scepticism about the real-world utility of existing sustainability courses [2]. Similar findings have emerged in comparative studies across the UK and Europe, where CE is often introduced

late or in isolation, rather than as a fundamental, integrative principle of spatial and urban design education [1,5,10].

To overcome the limits of both linear and overly technical circular models in architectural education, this article introduces a circular commons framework. This approach brings together ideas from commons theory, community involvement, and creating value in many ways. The approach transforms the way in which we see architects and others involved, as designers of material flows as well as stewards of shared environments, local resources, and collective memory. In this context, circularity serves as a means to drive social innovation, merging climate resilience, cultural heritage, and co-creation with the efficient use of resources and regenerative strategies. Based on systems thinking, teamwork, and real-world experience, the approach aims to help students develop critical thinking, creative problem-solving, and social fairness, along with the technical skills needed for sustainable practice.

Going beyond material-centric approaches and towards a more holistic integration of circularity into architectural education, this study pursues three core objectives:

1. **Critical Examination:** To analyse the limitations of dominant linear and material-centric CE models in architectural education, with particular attention to their tendency to privilege technical optimisation over social equity, participatory governance, and cultural relevance.
2. **Exploring Integration through Case Studies:** To investigate how circular economy (CE) principles are integrated into architectural and design curricula by examining five international cases (UK, Sweden, Egypt and the Netherlands). The analysis focuses on identifying strategies, outcomes, and pedagogical insights that illustrate both shared practices and context-specific approaches to embedding circularity in education.
3. **Defining the Circular Commons Framework:** To articulate the Circular Commons as a pedagogical framework and provide guidance for its operationalisation, which integrates technical, social, and cultural dimensions of circularity across multiple scales from materials and buildings to neighbourhoods and regional systems.

To achieve these objectives, the article first reviews existing literature on how CE principles are integrated into architectural education. It identifies the limits of linear and material-centric models. Next, it presents five international cases to highlight how CE principles are integrated into curricula, drawing on strategies, outcomes, and pedagogical insights. This is followed by a cross-case analysis that synthesises these findings, identifying convergent themes and contextual variations. In essence, these insights provide the premises for the proposed Circular Commons Framework as a guiding paradigm. Finally, the discussion and conclusion reflect on the implications of this framework for pedagogy and practice, outlining the challenges, limitations, and recommendations for advancing CE in design education.

2. Literature Review: Circular Economy (CE) in Architectural Pedagogy

The Circular Economy (CE) is widely defined as a regenerative economic model that separates economic growth from resource depletion by maintaining the value of products, materials, and resources for as long as possible while minimising waste [1–3]. Within architectural design, CE manifests as concepts such as design for disassembly (DfD), modularity, material passports, and adaptive reuse, which aim at reducing environmental impact [4–6]. CE in this field is not only technical, but also systemic, linking material flows with social, cultural, and governance dimensions of design practice [7,8].

Over the past decade, CE has gained significant prominence in policy, academia, and design discourse, though its intellectual roots extend much further. Early roots can be traced back to industrial ecology, cradle-to-cradle thinking, and regenerative design approaches

developed during the latter half of the twentieth century [9,11]. The concept began to gain global visibility with the establishment of the Ellen MacArthur Foundation in 2010, which collaborated across business, government, and academia to mobilise system solutions at all scales in CE [10,12]. By 2015, the European Union had formally embedded CE into its policy agenda through the Circular Economy Action Plan, consolidating its role in driving systemic economic change [13]. Since the mid-2010s, CE has increasingly been incorporated into architecture, urban planning, and design education, but more often through pilot workshops, electives, or sustainability modules rather than as a core, mainstream curricular component [8,14].

In architectural education, CE is being incorporated in different ways across global contexts. European initiatives such as the Horizon 2020 REPAiR project and the CircularCityChallenge have demonstrated how situated and challenge-based learning environments support students in applying CE principles through collaboration with local stakeholders [8,15]. Comparative studies reveal that CE is often introduced in advanced or elective modules; however, there is an increasing push to embed it across curricula from early stages to foster systemic thinking, collaborative making, and critical design agency [14,16]. In this sense, CE serves both as a technical toolkit for efficiency and as a pedagogical framework for transformation, shaping new competencies in sustainability-oriented architectural practice [17,18].

2.1. Technical Principles and Their Limitations

Historically, the built environment has operated on a “take-make-dispose” linear model, which not only accelerates resource depletion but also contributes to significant environmental waste and inefficiency [9,19]. CE frameworks aim to counter this trajectory, advocating for continuous resource loop systems where materials are reused, refurbished, recycled, or remanufactured, thereby extending their lifecycle and preserving value within the built environment [1]. This paradigm is embodied in multi-“R” strategies, such as the 10R and expanded 19R frameworks, which prioritise actions from “refuse” and “reduce” to “recover” and “remake” [20].

Contemporary architectural education often centres around these material-centric strategies, emphasising technical solutions like life cycle analysis (LCA), design for disassembly (DfD), and modularity [5,21]. As evidenced by curriculum analyses and expert surveys, technical competencies remain inadequately integrated into curricula, with circular economy appearing in less than 3% of Swedish architectural courses and typically addressed in isolated modules [14].

The dominance of material-centric approaches creates three interrelated problems. First epistemological narrowing: by privileging quantifiable metrics (carbon footprints, material circularity percentages, lifecycle costs), curricula devalue qualitative dimensions such as cultural meaning, spatial justice and community agency that resist standard measurement [14,16]. Design decisions are framed as optimisation problems with technical solutions, obscuring the social negotiations and value judgments inherent in determining what should be preserved, for whom, and through what processes.

Second, a professional misalignment: despite an emphasis on technical CE competencies, graduates report that real-world circular transitions require negotiation skills, stakeholder diplomacy, and an understanding of regulatory barriers, capacities that are rarely taught alongside material passporting or LCA [14,18]. Practitioners frequently encounter circularity as a governance challenge involving conflicting stakeholder interests, planning constraints, and community resistance, yet architectural education continues to frame it primarily as a material specification exercise.

Third, pedagogical fragmentation: as evidenced in Swedish data, CE appears in less than 3% of courses [14], with technical content remaining isolated in electives rather than being integrated across design studios, reinforcing circularity as a specialist add-on rather than a foundational design-thinking approach. This curricular marginalisation signals to students that CE competencies are supplementary to “real” architectural concerns of form, space, and aesthetics, undermining claims that sustainability represents a paradigm shift in design practice.

2.2. Why Material-Centrism Persists: Structural and Epistemological Factors

Despite widespread critique, material-centric CE pedagogy persists for structural, not merely pedagogical reasons. Understanding these factors is essential for developing alternative frameworks that can gain institutional traction.

First, alignment with industry metrics and professional validation: construction industry stakeholders are increasingly demanding lifecycle analysis, embodied carbon calculations, and material passports in procurement processes. Architectural curricula respond to this by teaching measurable technical skills that demonstrate graduate employability within existing professional frameworks. This creates a feedback loop where market demands shape educational priorities, which in turn reproduce market logics.

Second, assessment convenience: quantitative competencies, such as calculating material circularity indices, producing DfD specifications, are more straightforward to grade than qualitative skills like facilitating participatory workshops or negotiating stakeholder conflicts. In resource-constrained institutions facing large cohorts and limited staff time, standardised technical assignments offer efficiency that process-based or community-engaged projects cannot match [22,23].

Third, epistemological privilege of technical rationality: architectural education has historically valorised expert knowledge and technical expertise over participatory or vernacular approaches [23–25]. Material-centric CE fits comfortably within this tradition, positioning architects as technical specialists optimising resource flows rather than as facilitators of collective decision-making. Shifting to commons-oriented models requires confronting deeply embedded assumptions about professional authority and the architect’s role.

Fourth, institutional inertia and accreditation frameworks: architecture programmes operate within accreditation requirements that emphasise technical competencies and traditional studio outputs [26]. Introducing participatory, process-based, or commons-oriented approaches often required navigating bureaucratic approval processes, reallocating credits, and convincing validation panels that non-traditional pedagogies meet professional standards. Individual faculty champions can pilot innovations, but systemic curricular reform faced significant resistance.

These structural factors suggest that addressing the limitations of CE pedagogy requires not merely better teaching tools, but also institutional, professional, and epistemological shifts in how architectural education is conceived of, particularly in terms of design knowledge and practice.

2.3. Social Sustainability and the Commons in Architecture

The concept of the “commons” refers to shared resources, democratic spaces, and collective stewardship and provides a critical counterpoint to the material-centric orientation often found in CE education. Within architectural education, social sustainability is increasingly framed around inclusion, community agency, and cultural context, highlighting that design processes extend beyond technical optimisation. It manifests in the CE by focusing on the well-being of people and communities throughout a product’s life cycle. While CE is

usually linked to environmental and economic goals, a socially sustainable circular model consciously addresses issues of human development, equity, and inclusion.

In architectural education, this orientation translates into participatory approaches that encourage students to see themselves not only as designers of physical form but as facilitators of collective ownership and responsibility. In the UK, for instance, projects centred on urban seed exchanges, shared infrastructures, and time banks have demonstrated how architectural education can embed agency and collaboration within broader socio-spatial systems [17,18]. These initiatives position design as a medium for cultivating shared resources rather than producing discrete objects, reframing the architect's role from author to enabler.

The commons perspective also repositions architectural education as a civic and ethical endeavour rather than a product-driven exercise. It emphasises design as a process of negotiation, care, and ongoing maintenance, aligning closely with questions of governance, equity, and cultural continuity [24,26]. Recent studies reinforce this point by demonstrating how design studios can act as laboratories for social transformation, positioning students as co-producers of civic value and collaborative infrastructures [27,28]. Similarly, resilience-oriented teaching models emphasise the importance of integrating equity, stewardship, and adaptability into curricula, aligning CE pedagogy with the broader goals of climate-responsive and socially just urbanism [26,29,30]. These initiatives encourage students to reconceptualise architecture as a way to support social relations and community well-being, not just making individual buildings.

2.4. Why Commons Theory for Circular Economy Pedagogy?

The conceptual affinity between CE and commons frameworks justifies their integration. First, both challenge linear extraction-disposal models by emphasising resource stewardship over ownership, where CE proposes closing material loops, and commons scholarship examines governance of shared resources across generations [27,31]. Second, both require collective rather than individual action. CE transitions depend on coordinated behaviour across supply chains and user communities, mirroring the common theory that emphasises negotiated rules and mutual accountability [22,31]. Third, both position sustainability as socio-technical rather than purely technical. Just as effective commons governance integrates ecological knowledge with social norms and cultural practices, meaningful circularity requires technical strategies (DfD, material health) embedded within participatory decision-making and cultural context.

Crucially, commons frameworks foreground questions about architectural education often marginalises: Who governs shared resources? How are benefits and burdens distributed? Whose knowledge counts in design decisions? These questions are central to equitable circular transitions but remain peripheral in material-centric CE pedagogy. By integrating commons principles, collective stewardship, participatory governance, and recognition of diverse knowledge systems, architectural education can cultivate graduates capable of facilitating circular transitions that are not only technically sound but also socially just and culturally resonant.

Engaging with the commons also raises concerns of power, access, and justice. It compels students to ask who participates in design, whose voices are included, and how responsibilities and benefits are distributed across stakeholders [31]. These dimensions are particularly relevant for CE education, where the risk is that technical solutions dominate, sidelining the lived realities of communities and the socio-political dynamics of resource governance. Commons frameworks provide conceptual tools for making these dimensions pedagogically explicit rather than treating them as external to design competency.

2.5. Pedagogical Innovations and Persistent Gaps

Calls for pedagogical reform in architectural education have gained momentum, particularly emphasising systems thinking, experiential “hands-on” learning, scenario-based approaches, and contextual engagement with local challenges. Systems thinking enables students to recognise and design for complex, interlinked flows of materials, energy, value, and agency in built environments [8,32,33]. Scenario planning and live-build projects, as adopted in recent UK and European experiments, allow learners to grasp the practical and ethical dimensions of circular design, making visible the consequences of design decisions and the need for adaptive, collective action [17].

Despite these promising directions, three persistent gaps limit the transformation of CE pedagogy. First, fragmented delivery: pilot projects and elective modules demonstrate pedagogical innovation but rarely scale to core curriculum integration, leaving many students with minimal or no CE exposure [14,22]. Second, weak assessment infrastructure: while case studies document student engagement and qualitative learning, few programmes have developed systematic methods to evaluate circular competencies comparably across cohorts or institutions, hindering evidence-based pedagogical refinement [16,19]. Third, institutional barriers: resource constraints (limited staff training, crowded curricula, dependence on short-term project funding) combined with accreditation frameworks favouring conventional studio outputs restrict capacity for experimentation [22,23,25].

These gaps highlight the need for frameworks that are both ambitious in rethinking CE pedagogy and pragmatic in providing actionable strategies for diverse institutional contexts. Such frameworks must integrate technical CE competencies with social, cultural, and governance dimensions while providing guidance for embedding these principles across curricula, not merely in isolated interventions. They must also address assessment challenges, articulate clear learning progressions from introductory to advanced levels, and offer implementation strategies that acknowledge real-world resource constraints and institutional dynamics. The following sections examine how five international cases have attempted to navigate these challenges, providing empirical evidence for the development of such a framework.

3. Methodology

This study employs a qualitative comparative case study design combined with abductive analysis to investigate the integration of Circular Economy principles into architectural education and to develop a pedagogical framework grounded in these practices. The research progresses through three interconnected phases: (1) systematic identification and selection of cases through structured literature review; (2) within-case narrative analysis documenting pedagogical strategies, outcomes, and challenges; and (3) cross-case synthesis leading to framework development (Figure 1). This approach enables us to establish connections between empirical observations and theoretical interpretations, allowing the Circular Commons Framework to emerge from, rather than be imposed upon, the case evidence.

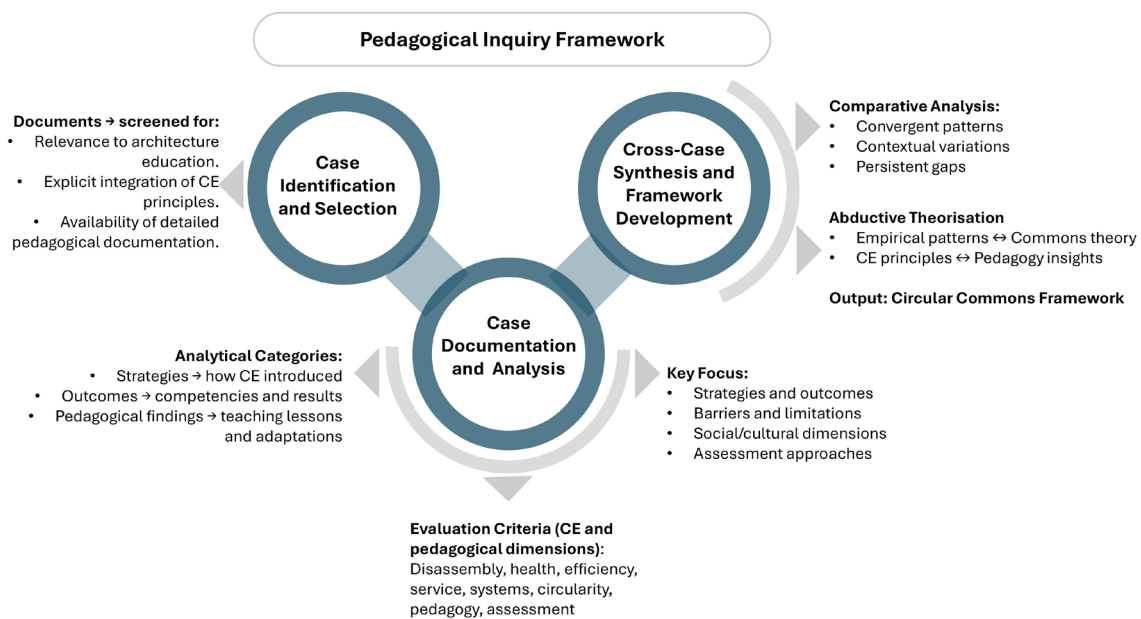


Figure 1. Methodological Framework for Investigating CE Integration in Architectural Education progresses through three phases: systematic case selection, case documentation and analysis using nine CE and pedagogical dimensions, and cross-case synthesis employing abductive logic to develop the Circular Commons Framework through iterative dialogue between empirical patterns and theoretical resources.

3.1. Comparative Case Study Approach

To investigate how circular economy (CE) principles are being embedded within architectural education, this study adopted a comparative case study approach [34,35]. This methodology allowed a structured comparison of diverse educational settings to identify common practices and context-specific practices.

Case selection proceeded through a systematic, multi-stage process. An initial literature search was conducted through Research Rabbit, a citation network visualisation tool selected for its ability to identify a network of interconnected publications and map thematic clusters around CE and architectural pedagogy. Starting with broad search terms such as “circular economy” in architectural education, design pedagogy, and circularity, the platform generated 72 documents, including journal articles, project reports, institutional case descriptions, and workshop documentation published between 2015 and 2024.

This approach has limitations. Research Rabbit privileges well-cited, English-language publications from institutions with strong digital presence, potentially underrepresenting pedagogical innovations from the Global South or smaller institutions with limited publication capacity. To mitigate this, the search was supplemented with direct examination of conference proceedings and grey literature from networks such as the Circular City Challenge [15] and European Horizon 2020 projects.

Following this, a systematic literature review was conducted, which included screening these sources in several stages: first, for relevance to architectural education (as opposed to the broader built environment); then, for evidence of the pedagogical application of CE principles; and finally, for the availability of detailed information on course design, teaching activities, and outcomes. Through this iterative process, the pool was narrowed to five cases.

In selecting these cases, a set of inclusion and exclusion criteria was applied. The inclusion criteria required that each case engage directly with architectural education at either the undergraduate or postgraduate level. Next, each case must demonstrate an explicit integration of CE principles in its curricular or pedagogical design. The third requirement

was that each case must have sufficient documentation, such as syllabi, workshop reports, evaluations, or peer-reviewed publications, for meaningful analysis. It was also ensured that each case represents geographic diversity, academic levels, and instructional formats to gather context-specific insights.

Conversely, the exclusion criteria ruled out programmes that referenced sustainability in generic terms without specific engagement with CE concepts. The cases that focused solely on technical training without any corresponding pedagogical innovation and those that were mono-disciplinary and lacked collaboration or transdisciplinarity were excluded.

Through iterative screening, five cases were selected that collectively offer: (a) pedagogical diversity across undergraduate, postgraduate and continuing professional development levels; (b) geographic variation spanning Northern and Southern Europe, North Africa, and including both resource-rich and resource-constrained contexts; (c) methodological range including studios, workshops, electives and living labs; and (d) sufficient documentation for analytical depth. Rather than seeking identical cases for strict comparison, this purposive selection strategy enabled the examination of how CE principles adapt to different institutional, cultural, and resource contexts, a key consideration for developing transferable yet contextually sensitive pedagogical frameworks.

Researcher Positionality and Bias Mitigation

The authors are architectural educators with a commitment to sustainability pedagogy, which has shaped their interpretive lens in recognising the value of participatory and commons-oriented approaches. This positionality created a potential for confirmation bias, favouring cases that demonstrate social engagement over purely technical implementations. To mitigate this bias, several strategies were employed: both researchers independently analysed cases using the nine-dimension framework, then compared interpretations to identify discrepancies. Disagreements—for example, whether Ulster’s CPD workshops primarily constituted “systems thinking” or “cultural learning,” or whether Swedish modules sufficiently operationalised social equity, were resolved through discussion and re-examination of the source texts rather than defaulting to initial interpretations. Where interpretation remained contested or evidence was ambiguous (such as assessing the depth of stakeholder engagement in cases with limited documentation of power dynamics), these limitations were noted in case descriptions rather than making definitive claims.

3.2. Analysis of Cases

For each selected case, documentary evidence, including published research articles, course syllabi, project reports, workshop documentation, student workshop documentation, student work samples (where available), and institutional descriptions, was compiled. Analysis focused on three dimensions: (1) pedagogical strategies: how CE principles were introduced, structured, and scaffolded; (2) learning outcomes: documented changes in student competencies, understanding, or practice; and (3) implementation challenges: barriers, gaps, or limitations identified by educators or students.

Given the documentary nature of evidence, observing pedagogical practices directly or interviewing participants was not possible, which constrains interpretation. Hence, reported experiences rather than lived realities were analysed. The study also acknowledges that published accounts may emphasise successes over failures or present idealised versions of practice.

To structure comparison, each case was analysed through nine dimensions derived from CE and design education literature (Figure 1):

- **Design for Disassembly:** Designing buildings and components so they can be easily dismantled, reused, or adapted at the end of their life cycle.

- **Material Health:** Ensuring materials are non-toxic, durable, and traceable throughout their lifecycle for safe reuse and regeneration.
- **Resource Efficiency:** Reducing waste and maximising the effective use of materials, energy, and water within design and construction processes.
- **Product-as-a-Service:** Shifting from ownership to service-based models where products are leased, maintained, or upgraded rather than discarded.
- **Systems Thinking:** Understanding design decisions as part of interconnected ecological, cultural, economic, and social systems.
- **Circular Design (Reuse, Repair, Refurbish, Recycle, Adapt):** Embedding iterative material loops that extend the lifecycle of resources and components.
- **Pedagogical Core:** The central teaching strategies, such as challenge-based learning, live projects, or gamification, that structure CE education.
- **Assessment and Feedback:** Mechanisms to evaluate learning outcomes, including peer review, stakeholder input, and reflective self-assessment.
- **Social Equity and Cultural Agency:** Addressing who participates in circular decisions, how benefits and burdens are distributed across communities, whose knowledge systems (professional, vernacular, indigenous) are recognised as legitimate, and whether circular systems empower marginalised communities or perpetuate existing inequalities.

The synthesis resulted in a matrix of CE pedagogy, demonstrating how circularity is framed, processed, and assessed, as well as identifying areas where gaps remain.

Selected Cases

The following five cases analysed in this study illustrate diverse approaches to embedding circular economy (CE) principles in architectural and design education across different geographic, cultural, and institutional contexts.

1. **Queen's University Belfast (UK): School of Natural and Built Environment—Year 1 Undergraduate-** Embeds circularity early through multi-scalar studio projects and live-build exercises using reclaimed materials [16].
2. **Swedish Architecture Institutions (Sweden): Chalmers, KTH, Lund, Jönköping, Luleå—Undergraduate and Postgraduate-** Integrates CE into architecture and engineering curricula through systematic competency frameworks and cross-disciplinary sustainability modules [14].
3. **Cairo University (Egypt): Faculty of Engineering, Department of Architecture—Undergraduate and CPD-** Employs gamification and simulation tools (action cards, design wheels, calculators) to operationalise CE strategies in accessible and interactive ways [19].
4. **Ulster University (UK): School of Architecture and Built Environment—CPD and Lifelong Learning-** Uses practice-led CPD workshops informed by Global South precedents to address cultural, regulatory, and social barriers to circularity [18].
5. **TU Delft (Netherlands): Faculty of Architecture and the Built Environment—Master's (Urbanism/Architecture)—**Advances transdisciplinary design studios and living labs where CE is applied through systems mapping, stakeholder workshops, and eco-innovative regional projects [8].

3.3. Cross-Case Synthesis and Framework Development

Framework development followed an abductive logic [36], moving iteratively between empirical observations and theoretical interpretation. Rather than testing a predetermined hypothesis or purely inductively generating a theory from data, we engaged in continuous dialogue between:

- Empirical patterns observed across cases (e.g., recurring emphasis on stakeholder participation, integration of local knowledge, multi-scalar thinking)
- Theoretical resources from commons scholarship [22,27,31], participatory design literature [37,38], and CE frameworks [1,10,19]
- Pedagogical gaps identified in both literature and case evidence (lack of social-cultural integration, peripheral elective delivery, weak assessment)

This process revealed that existing CE pedagogical models inadequately addressed the collective, participatory, and culturally situated dimensions evident in successful case implementations. Commons theory offered a conceptual lens to theorise these dimensions: both CE and commons frameworks prioritise shared resources over individual ownership, require collective governance, and challenge linear extraction-disposal models. However, commons theory had not been systematically applied to architectural education contexts.

The Circular Commons Framework thus represents a theoretical synthesis, integrating commons principles (collective stewardship, participatory governance, and cultural situatedness) with CE technical strategies (material loops, lifecycle thinking, and regenerative design), as well as design pedagogy insights (experiential learning, systems thinking, and stakeholder engagement).

4. Case Documentation and Analysis

Since the case evidence was drawn primarily from published papers and project reports, descriptions of formal strategies (e.g., syllabi, studio briefs, pedagogical tools) were often embedded within narratives of how students and educators experienced these activities in practice. The case narratives articulate structural intentions, offering a comprehensive view of how circular economy principles were integrated and encountered in architectural education.

4.1. Queen's University Belfast (UK): Studio-Based Undergraduate Education

The Department of Architecture and Planning at Queen's University Belfast integrates circular economy principles into first-year undergraduate education through a semester-long sequence of four interlinked studio projects. This programme responds to the pressing challenge of the UK's construction and demolition sector, which generates approximately 62% of the nation's waste, and responds to the imperative of embedding circularity early in design education [16].

The strategies employed span macro- to micro-scales, encompassing projects entitled Co-lab, Sharing Everything, Making Together, and Future Scenarios. These projects progressively introduce students to circularity by addressing city- and neighbourhood-scale issues, material and building-detail explorations, and speculative future scenarios. Pedagogical tools include systems-thinking exercises, precedent analysis of circular design practices, material storytelling, and hands-on live-build experiences at 1:1 scale using reclaimed or waste materials. Circularity is also introduced through analogies such as "sharing," which frame collaboration and resource exchange as central design concepts. External collaborations with experts in fields such as crafts, fashion, and engineering further extended the learning environment, providing students with exposure to real-world waste streams and circular practices [16].

The outcomes of this approach were visible in both student reflections and educator observations. Learners progressed from vague conceptualisations of sustainability to informed and critically engaged understandings of circularity, demonstrating the ability to apply technical, environmental, and social dimensions of circular design within their projects. Precedent-based analysis evolved into evaluative judgement of circular principles, such as design for disassembly, resource sharing, and regenerative practices. Students

also developed stronger systems thinking across scales, alongside empathy in user profile exercises, and greater confidence in embedding circular approaches into design and construction [16].

The pedagogical findings highlight the effectiveness of multi-scalar design briefs, embodied learning, and collaborative engagement in building circular design literacy. Sequencing projects by scale and theme fostered cumulative learning, while alternating group and individual projects enhanced both collaborative and independent problem-solving skills. Engagement with external experts cultivated hands-on learning skills, including project management and conflict resolution. Yet, the intervention revealed a lack of quantitative assessment tools to measure circular competencies. This suggests that future iterations could benefit from longitudinal evaluation and broader cross-institutional resource sharing to strengthen circular pedagogy.

4.2. Sweden: Circular Curriculum Interventions in Schools of Architecture

Sweden's national commitment to sustainability has driven curricular reforms across architecture and civil engineering programmes. Within the Swedish Universities of the Built Environment (SBU) network, comprising Chalmers University of Technology, KTH Royal Institute of Technology, Lund University (LTH), Jönköping University (JU), and Luleå University of Technology (LTU), efforts have been made to embed circular economy (CE) content into degree structures. A recent review of 426 compulsory syllabi revealed that fewer than 3% explicitly addressed CE principles, underscoring the challenge of integrating circularity into mainstream curricula [14].

To address this gap, institutions introduced standalone courses such as Sustainability Transitions and Environmental and Resource Analysis at Chalmers, Building Materials and Natural Resources Theory at KTH, waste-focused teaching through Waste Science and Technology at LTU, and the module Sustainable Product Realisation at JU. Lund University incorporated circular processes into its technical courses. Cross-disciplinary and applied exercises included systems mapping, resource audits, adaptive reuse projects, and digital simulations of resource loops. Beyond the classroom, collaborative experiments such as urban living labs and "material passports" encouraged dialogue between students, municipalities, and industry partners, framing CE as both a technical and socio-cultural challenge.

The interventions produced encouraging but uneven results. Students demonstrated a stronger understanding of resource efficiency, lifecycle thinking, and adaptive design. It was evident in the assignments and reflective work and demonstrated an ability to link technical strategies to governance and community participation. However, graduate feedback and industry surveys revealed persistent concerns about fragmentation on CE content. CE was frequently confined to electives or isolated modules rather than embedded across the curriculum, which limited its coherence as a professional competency framework. Key skills such as reusability, material properties, and construction technology were inconsistently developed across programmes, leading practitioners to view graduates as conceptually aware but insufficiently prepared for practical application in the construction sector. This misalignment between curricular exposure and professional expectations suggests that the integration of CE content has not yet reached the depth required for effective sectoral transition [14].

The Swedish experience illustrates both the opportunities and limits of CE pedagogy in architectural education. Simulation tools and participatory projects proved highly effective in cultivating critical thinking, transversal skills, and socio-technical awareness. Students appreciated cross-disciplinary engagement and the opportunity to collaborate with external stakeholders. It heightened their appreciation of the circular economy as a systemic challenge. However, structural barriers limited the reach of these initiatives.

CE often remains an add-on subject rather than a core curricular principle that reflects broader constraints such as limited curriculum space, time pressures within degree structures, accreditation requirements, and gaps in staff expertise. This suggests that, while Sweden pioneered innovative CE teaching practices, moving from isolated experiments into systemic, compulsory frameworks will require stronger institutional support. Only through this shift can CE pedagogy move from supplementary content to a transformative force in shaping the next generation of architects and engineers.

4.3. Cairo University (Egypt): Gamification and Simulation-Based Pedagogy

At Cairo University, the Department of Architecture developed a pioneering framework designed to equip both undergraduate students and continuing professional development (CPD) learners with practical competencies in circular design. The initiative emerged in response to a recognised knowledge gap in the African context, where circularity is often underrepresented in architectural curricula and where clarity in design methodologies is especially needed. By operationalising circular economy (CE) principles through accessible, assessable strategies, the programme sought to bridge this gap and expand the scope of circular pedagogy beyond conventional academic audiences [19].

The strategies employed were centred on gamification and simulation tools that translate complex CE concepts into interactive and iterative learning experiences. Key pedagogical devices included a process board mapping the stages of architectural design, a circular design wheel, and over 90 action cards that outlined specific circular strategies. These were complemented by a digital calculator that allowed learners to assess circularity quantitatively within their projects. Learners engaged in iterative exercises such as mapping available waste before design conception, applying material passports, and integrating collaborative stakeholder involvement. Emerging technologies, including artificial intelligence and digital marketplaces, were also incorporated to provide rapid assessment and feedback, making circular decision-making more tangible and accessible.

The outcomes of the initiative were validated through surveys of 45 international experts, which confirmed the effectiveness of early-stage resource mapping and iterative learning cycles. Among the strategies trialled, “design with the right resources” was identified as having the highest potential circular impact. The pedagogy also helped introduce and legitimise new professional roles, such as circularity consultant and connector, highlighting the expanding ecosystem of expertise required for circular transitions. Furthermore, the gamified framework enabled structured, objective assessment through the circularity calculator, offering learners clear and actionable feedback to guide design decisions. This approach proved particularly effective for non-experts and lifelong learners, who benefited from the quick and engaging entry points into circular practice [19].

The pedagogical findings highlight the potential of gamification to enhance engagement, accelerate knowledge acquisition, and provide transparent evaluation methods. By integrating multiple tools and strategies across all phases of design, the framework encourages learners to experiment, compare alternatives, and adapt their approaches iteratively. The adopted methodology addressed the dual challenge of complexity and uncertainty that hinders the adoption of CE in practice. Future research could test the framework further in live workshop settings and evaluate its impact on larger cohorts. This action would validate the model as a scalable and adaptable approach for circular design education in diverse contexts.

4.4. Ulster University (UK): Contextual CPD and Practice-Led Workshops

At Ulster University, the School of Architecture introduced a practice-led continuing professional development (CPD) curriculum that addresses the regulatory, cultural, and

social barriers that often limit the adoption of circular economy (CE) principles. Designed for both professional and lifelong learners, the programme draws inspiration from Global South precedents where resource constraints have historically fostered adaptive and vernacular strategies for reuse and resilience. This contextual framing enables participants to go beyond standardised Western narratives of circularity and engage with approaches that reflect diverse material cultures and socio-economic realities [18].

The strategies employed include workshops centred on real-world case studies from the Global South, which involved material recovery, incremental adaptation, and community-led reuse. The application of established frameworks such as the 10R and extended 19R models encouraged learners to understand circularity as a spectrum of possible actions, ranging from refusal and reduction to repurposing and regeneration. The critical application of the frameworks allowed participants to question their capabilities in varied contexts. Peer-to-peer exchanges and cross-disciplinary collaboration facilitated by workshops involved architects, planners, engineers, and policy specialists. The discussion was framed around regulatory constraints, adaptive reuse opportunities, and locally driven material innovations. These workshops encouraged learners to evaluate the challenge in question and apply technical solutions within broader socio-cultural and regulatory environments.

The outcomes indicate that participants gain a deeper understanding of circularity by approaching it through the lenses of social value, resource limitation, and policy frameworks. Learners developed the ability to assess why circular practices work in some contexts and stall in others, by correlating the outcomes to systemic issues such as governance, cultural acceptance, or economic feasibility. Reflection emerges as the key to adapt lessons from diverse contexts into strategies suitable for their own practice. The ongoing engagement also fostered an appreciation of circularity as a dynamic process rather than a static checklist of actions [18].

The pedagogical findings highlight the significance of contextualisation and dialogue in embedding CE within professional practice. By foregrounding vernacular techniques and adaptive reuse, the programme challenges assumptions about linear design culture and reinforces circularity as both a technical and cultural pursuit. Participants reported improved systems thinking, enhanced understanding of regulatory and social barriers, and an expanded capacity to adapt circular strategies to local needs and resources. Overall, the Ulster model illustrates how CE education can transcend technical optimisation to cultivate critical, culturally attuned professionals who can navigate and negotiate circularity in complex real-world contexts.

4.5. TU Delft (Netherlands): Situated, Transdisciplinary Learning in Design Studios

At Delft University of Technology, the Department of Urbanism piloted the integration of circular economy (CE) concepts into master 's-level design studios through the EU-funded REPAiR Project. This initiative positioned CE not simply as a technical exercise but as a spatial and systemic challenge, foregrounding the relationship between resource flows, spatial quality, and governance. Students were directly engaged in live regional projects and living labs, where they encountered the complexities of applying circular strategies across multiple scales of urbanism [8].

The strategies underpinning this pedagogy were embedded in courses such as Spatial Strategies for the Global Metropolis and Geodesign for a Circular Economy in Urban Regions. The studios combined analytical tools, stakeholder workshops, and interdisciplinary teamwork, which brought together students from urbanism, architecture, landscape architecture, and industrial ecology. The process commenced with resource flow analysis and mapping systemic spatial structures, which provided the basis for iterative design

development. Students then worked closely with external stakeholders, including policymakers, regional planners, and business representatives, to refine and advance their proposals. The transdisciplinary nature of this model exposed students to diverse expertise and real-world constraints.

The outcomes of this approach were significant. Over successive cohorts, students moved from a basic conceptual understanding of circularity to developing complex systems-thinking and eco-innovative design solutions. Their outputs, ranging from strategies for circular food systems to modular urban regeneration frameworks, were frequently validated as relevant and, in some cases, superior by the regional stakeholders involved. Feedback confirmed that students expanded their vision from short-term problem-solving to long-term strategies of transition and disruption, demonstrating an ability to link technical design with systemic change [8].

The findings highlight the value of situated transdisciplinary learning in accelerating the integration of circular concepts. Collaboration with researchers and practitioners, ongoing stakeholder engagement, and exposure to conflicting values or objectives led effective reflections and innovative results. However, the model required high staff resources and careful planning, as well as flexibility and commitment from both educators and external partners. Ethical issues, such as transparency in combining education and research, necessitated a thoughtful balance between academic learning goals and the practical demands of external partners. TU Delft's experience demonstrates the prospect of living-lab studios in preparing future professionals to lead systemic circular transitions.

5. Cross-Case Synthesis

The comparative analysis of the five cases reveals converging pedagogical patterns alongside context-specific variations that inform the development of a transferable yet adaptable framework for CE integration in architectural education. While cases span diverse institutional contexts, educational levels, and geographic settings (Table 1), consistent themes emerge around practical pedagogical approaches. Simultaneously, significant gaps persist that current initiatives have not adequately addressed. This synthesis identifies both the foundations for transformative CE pedagogy and the barriers requiring systemic intervention.

Table 1. Comparative analysis of five cases demonstrating diverse approaches to integrating circular economy principles in architectural education.

Dimension	Queen's Belfast (School of Natural and Built Environment— Year 1 Undergraduate)	Swedish Universities (Chalmers, KTH, Lund, Jönköping, Luleå— Undergraduate and Postgraduate)	Cairo University (Faculty of Engineering, Department of Architecture— Undergraduate and CPD)	Ulster University (School of Architecture and Built Environment— CPD and Lifelong Learning)	TU Delft (Faculty of Architecture and the Built Environment— Master's (Urbanism/ Architecture)
Design for Disassembly	1:1 live-builds with reclaimed materials; precedent analysis	Modules on adaptive reuse and resource loops	Action cards, circular wheel; iterative design simulations	Case studies of vernacular adaptive reuse	MSc studios focused on adaptive systems and modularisation
Material Health	Material storytelling and hands-on testing	Simulation of material flows and passports	Material passports; calculator tracks durability/toxicity	Exploration of local/vernacular material innovations	Stakeholder validation of eco-materials and cycles

Table 1. *Cont.*

Dimension	Queen’s Belfast (School of Natural and Built Environment— Year 1 Undergraduate)	Swedish Universities (Chalmers, KTH, Lund, Jönköping, Luleå— Undergraduate and Postgraduate)	Cairo University (Faculty of Engineering, Department of Architecture— Undergraduate and CPD)	Ulster University (School of Architecture and Built Environment— CPD and Lifelong Learning)	TU Delft (Faculty of Architecture and the Built Environment— Master’s (Urbanism/ Architecture)
Resource Efficiency	Projects linking city/neighbourhood scales to resource mapping	Systems-mapping of urban waste and resource audits	AI-enabled resource calculators	Emphasis on resource- constrained Global South contexts	Urban/regional flow analyses to optimise resource loops
Product-as-a- Service	Introduced conceptually in future scenarios	Discussed in elective workshops but not mainstreamed	Service-based design scenarios in gamified modules	Explored via professional reflection in CPD settings	Considered in regional planning and governance models
Systems Thinking	Scaffolded across projects from micro to macro	Mapping of waste/resource flows in studio	Framework wheel integrates systemic strategies	Reflective dialogue on regulatory/social barriers	Central to MSc studio methodology (Scales and Aspects model)
Circular Design (Reuse, Repair, Refurbish, Recycle, Adapt)	Progressive design briefs linking circular practices	Modules emphasising reuse and recycle loops	Iterative design testing with 90+ action cards	Workshops on repair/adaptation in constrained contexts	Advanced projects addressing multiple circular loops
Pedagogical Core	Studio-based, multi-scalar, collaborative	Elective modules + living labs	Gamification and simulation	CPD workshops with reflective practice	Situated design studios with transdisciplinary collaboration
Assessment and Feedback	Peer-to-peer critique + expert input	Reflective assignments; surveys of graduates	Circularity calculator + expert surveys	Peer reflection + critical dialogue	Stakeholder validation + reflective critique
Social Equity and Cultural Agency	Implicit through external craft/fashion collaborations; community sharing analogies; not explicitly framed as equity	Mentioned in socio-technical awareness discussions; equity not operationalised; community participation acknowledged but peripheral	Minimal—primary focus on tool accessibility for non-experts; equity dimensions absent	Strong —explicit cultural context via Global South precedents; vernacular knowledge validation; addresses resource justice	Stakeholder engagement with municipali- ties/businesses; limited explicit critique of power distribution or environmental justice

5.1. Convergent Pedagogical Patterns

Five pedagogical characteristics emerged consistently across cases as foundational to effective CE integration, regardless of institutional context or educational level.

- **Multi-scalar systems thinking:** All five cases scaffold learning across scales from materials and components through buildings to neighbourhoods and regions, enabling students to understand circularity as interconnected material, social, and governance flows rather than isolated technical interventions. Queen’s University Belfast advanced students from city-scale resource mapping to building details and speculative futures [16]. Swedish electives employed systems mapping of waste flows across governance levels [14]. TU Delft’s studios connected spatial strategies with regional

resource loops [8]. This multi-scalar approach proved essential for moving beyond component-level optimisation towards systemic design thinking.

- **Experiential and embodied learning:** Hands-on, iterative, materially grounded and gamified learning pedagogies consistently enhanced engagement and accelerated competency development, particularly for early-stage learners. Queen's Live—building projects using reclaimed materials at 1:1 scale transformed abstract sustainability discourse into an embodied practice [16]. Cairo's gamification framework, which includes action cards, design wheels, and circularity calculators, provided an interactive iteration that proved especially effective for non-experts [19]. Swedish students valued practical experiments and reflection over passive lecture formats [14]. These approaches made circular principles tangible, fostering experimentation and creative problem-solving through direct material engagement.
- **Stakeholder engagement and real-world challenge framing:** Authentic collaboration with external stakeholders such as industry partners, municipal planners, and community groups consistently enhanced learning relevance and professional skill development. TU Delft students engaged policymakers and businesses to test regional interventions, receiving validation that proposals were professionally relevant [8]. Ulster workshops drew on Global South case discussions linking professionals with diverse regulatory and cultural contexts [18]. Swedish electives involved local governments in resource mapping and adaptive reuse strategy co-development [13]. Queen's collaborations with craftspeople and engineers exposed students to material cultures beyond architectural conventions [16]. This stakeholder integration positioned circularity as a negotiated practice shaped by values and constraints, not merely a technical specification.
- **Transdisciplinary collaboration:** Working across disciplinary boundaries such as architecture, urbanism, engineering, planning, and policy proved essential for innovation and contextual responsiveness. TU Delft positioned students from multiple disciplines in teams designing systemic solutions [8]. Ulster workshops facilitated dialogue among architects, engineers, and policy professionals [18]. Swedish modules partnered students with governance bodies and community stakeholders [14]. Queen's invited experts from crafts, fashion, and engineering into design processes [16]. This co-production of knowledge supported context-sensitive outcomes, fostered adaptability, and challenged disciplinary silos hindering educational reform.
- **Assessment and feedback mechanisms integrating multiple perspectives:** Effective CE pedagogy employed diverse evaluation approaches combining technical metrics, peer critique, stakeholder validation, and reflective self-assessment. Cairo University's circularity calculator provided quantitative feedback enabling structured, objective evaluation particularly valuable for non-experts [19]. Queen's utilised peer-to-peer critique and external expert input, reinforcing shared responsibility and collaborative judgement [16]. TU Delft stakeholder workshops enabled external actors to validate project proposals, embedding professional expectations into evaluation and demonstrating real-world relevance [8]. Swedish programmes introduced reflective assessment models asking students to narrate how systems thinking and stakeholder collaboration informed design decisions, linking technical outputs to critical reflection [14]. Ulster integrated peer and stakeholder review within CPD contexts [18].

A critical gap persists. Cases lack shared benchmarks or comparable tools for measuring circular competencies across institutions or cohorts. Assessment approaches remained localised and context-specific, limiting the ability to demonstrate pedagogical effectiveness systematically, refine methods based on evidence, or establish CE competencies as standardised professional requirements. This gap indicates that while diverse assessment modes

prove pedagogically valuable, the field requires coordinated development of evaluation frameworks enabling both contextual adaptation and cross-institutional comparison, which the Circular Commons Framework must address.

5.2. Context-Specific Variations and Adaptations

While convergent patterns emerged, effective implementation varied significantly based on institutional resources, educational level, cultural context, and regulatory environment, underscoring the need for adaptable rather than prescriptive frameworks.

- Educational level shaped pedagogical approach: Undergraduate programmes (Queen's, Cairo) emphasised foundational concepts, accessible entry points, and scaffolded progression, using analogies ("sharing"), gamification, and embodied making to build initial competency [16,19]. Postgraduate programmes (TU Delft) assumed technical literacy, focusing on complex systems analysis, stakeholder negotiation, and strategic intervention at urban/regional scales [8]. CPD initiatives (Ulster, Swedish modules) addressed the professional practitioners' need for regulatory navigation, cultural adaptation, and integration with existing practice [14,18]. This variation suggests frameworks must articulate clear learning progressions rather than one-size-fits-all approaches.
- Resource availability constrained pedagogical ambition: TU Delft's living labs required substantial staff resources, careful coordination, and committed external partnerships, feasible within well-funded EU research projects but challenging to sustain or scale [8]. Queen's live-builds depended on individual instructor commitment and external collaborations, which were negotiated on a case-by-case basis [16]. Swedish initiatives faced curriculum space constraints and gaps in staff CE expertise, limiting expansion beyond electives [14]. Cairo's gamification tools offered resource-efficient alternatives, enabling rapid implementation with limited infrastructure [19]. These variations indicate that successful frameworks must accommodate diverse resource contexts, offering both high-investment, transformative models and accessible, entry-level interventions.
- Cultural and regulatory contexts shaped circular strategies: Ulster's focus on Global South precedents acknowledged that circularity manifests differently under resource constraints, with vernacular adaptive reuse practices offering insights unavailable from Northern European contexts [18]. Cairo's framework addressed African knowledge gaps and pedagogical needs distinct from European sustainability discourse [19]. Swedish initiatives navigated Nordic policy environments with firm sustainability commitments but regulatory barriers to adaptive reuse [14]. This contextual variation validates the commons framework's emphasis on cultural situatedness and the integration of local knowledge, rather than relying on universal technical protocols.

5.3. Persistent Gaps and Barriers

Despite pedagogical innovations, three critical gaps emerged consistently across cases, representing systemic barriers requiring institutional and professional intervention beyond individual pedagogical creativity.

- Fragmented curricular delivery: CE remains confined mainly to electives, workshops, and pilot projects rather than being integrated across core curricula. Swedish data showing CE in fewer than 3% of compulsory courses [14] exemplifies broader fragmentation. Even successful interventions (Queen's studios, TU Delft living labs) functioned as isolated innovations dependent on individual champions rather than institutionalised structures [8,16]. This marginalisation signals to students that circularity is supplementary to "real" architectural concerns, undermining claims that sustainability represents a paradigm shift in design practice.

- Weak and uneven assessment infrastructure: Few programmes demonstrated systematic competency evaluation enabling comparison across cohorts or institutions. Queen's identified a lack of quantitative assessment tools as a key limitation [16]; Swedish graduates and practitioners reported inconsistent skill development [14]; Cairo's circularity calculator offered quantitative metrics but remained isolated from broader professional competency frameworks [19]. Without robust assessment, pedagogical effectiveness remains difficult to demonstrate, refine, or establish as a legitimate professional requirement.
- Institutional inertia and structural barriers: Resource constraints (limited staff training, crowded curricula, short-term funding), accreditation frameworks favouring conventional studio outputs, and gaps in staff expertise consistently restricted innovation [14,22,23]. Swedish institutions struggled to mainstream CE despite national sustainability commitment [14]; Queen's success depended precariously on individual instructor commitment [16]; TU Delft's resource-intensive model proved difficult to sustain beyond funded project periods [8]. These structural factors suggest that addressing the limitations of CE pedagogy requires not merely better teaching tools, but also institutional, professional, and epistemological shifts in how architectural education conceives of design knowledge and practice.
- Peripheral treatment of social equity and cultural agency: Despite rhetoric about holistic circularity, cases prioritised technical competencies (material flows, lifecycle metrics) over social dimensions (equity, justice, power). None systematically addressed: environmental justice in circular infrastructure siting; epistemological decolonisation beyond citing Global South "examples"; or power redistribution in collaborative governance. Even stakeholder engagement often remained consultative rather than genuinely redistributing decision-making authority. This gap reflects broader tendencies in architectural education to treat social concerns as supplementary to technical expertise [23,24], suggesting that CE pedagogy replicates rather than challenges professional culture, which privileges technical rationality over social practice.

5.4. Implications for Framework Development

The convergent patterns, contextual variations, and persistent gaps collectively inform requirements for the proposed Circular Commons Framework. A practical framework must:

- Integrate technical and social dimensions: Cases demonstrate that material-centric technical skills (LCA, DfD, material passporing) prove insufficient without capacities for stakeholder negotiation, cultural contextualisation, and governance navigation [14,18]. The framework must position technical competencies within broader social, cultural, and governance literacies, not as separate domains but as interdependent dimensions of circular practice.
- Enable contextual adaptation while maintaining coherence: The framework cannot prescribe universal implementation given documented variations in resources, educational levels, and cultural contexts. It must offer flexible guidance enabling institutions to adapt strategies to local conditions while maintaining conceptual coherence around core principles of collective stewardship, participatory governance, and cultural situatedness.
- Address assessment systematically: Given persistent evaluation gaps, the framework must propose concrete assessment approaches integrating quantitative metrics (circularity calculations, technical specifications) with qualitative evaluation (stakeholder feedback, reflective practice, collaborative capacity).
- Provide implementation strategies acknowledging institutional barriers: The framework must articulate not only what should be taught but how to navigate accreditation

requirements, resource constraints, and institutional inertia. This includes guidance for incremental integration (elective → studio → programme-wide), staff development strategies, and the sharing of inter-institutional resources.

These implications directly inform the Circular Commons Framework's structure and operationalisation guidance, positioning it as a response to documented pedagogical needs rather than theoretical abstraction.

6. Conceptual Framework: The Circular Commons

The cross-case analysis reveals that effective CE pedagogy requires integration of dimensions currently fragmented across initiatives: technical circular strategies, cultural and local knowledge, collaborative governance structures, and iterative experiential learning environments. Existing frameworks privilege either technical efficiency (material passporting, lifecycle analysis) or social engagement (participatory design, stakeholder workshops) without adequately synthesising these dimensions. The Circular Commons Framework addresses this gap by theorising the empirical patterns documented in Section 6 through commons scholarship [22,27,31], positioning circularity as collective stewardship of shared material, spatial, and knowledge resources rather than individual technical optimisation.

The framework addresses persistent challenges identified across cases: fragmented curricular delivery, weak assessment infrastructure, and institutional barriers that confine CE to elective status. By integrating technical competencies with social, cultural, and governance literacies and providing concrete operationalisation guidance, the framework offers both conceptual coherence and practical implementation strategies for diverse institutional contexts. Table 2 documents the empirical grounding of each framework component in case evidence, demonstrating that the framework synthesises documented practices rather than imposing external theory.

Table 2. Empirical grounding of Circular Commons Framework components in case evidence. Each component synthesises convergent patterns documented across five cases, demonstrating that the framework emerges from documented practices rather than imposing external theory.

Framework Components	Defining Characteristics	Evidence from Cases
Circular Design Practices	Technical CE strategies: DfD, material health, resource efficiency, adaptive reuse, regenerative loops; multi-scalar systems thinking	Queen's: DfD precedent analysis, live-builds with reclaimed materials, multi-scalar studio progression; Swedish: Systems mapping, resource audits, lifecycle analysis modules; TU Delft: Regional resource flow analysis, adaptive urban systems; Cairo: Design wheel integrating circular strategies across project phases
Local Knowledge and Cultural Practices	Vernacular traditions, place-based expertise, Global South precedents, cultural relevance, narrative construction	Ulster: Global South adaptive reuse precedents, vernacular techniques; Queen's: Material storytelling, external craft/fashion collaborations; Cairo: Context-specific tools addressing African knowledge gaps; Swedish: Municipal partnerships grounding strategies in local conditions
Collaborative Governance	Stakeholder engagement, participatory workshops, co-design processes, negotiation across conflicting interests, and power-sharing mechanisms	TU Delft: Stakeholder workshops with policymakers/businesses, iterative co-design; Swedish: Municipal and industry partnerships, community collaboration; Ulster: Cross-disciplinary professional dialogue (architects/engineers/policy); Queen's: External expert collaboration, peer critique structures
Circular Synergy Workshops	Experiential, iterative learning environments; gamification; live-builds; scenario testing; rapid feedback cycles	Cairo: Gamification tools (action cards, calculator), iterative strategy testing; Queen's: 1:1 live-build projects, hands-on material experimentation; Swedish: Digital simulations, practical experiments valued over lectures; TU Delft: Living lab studios with real regional projects

6.1. Components of the Circular Commons Framework

The concept of the Circular Commons can be defined as a dynamic socio-spatial process that emphasises community agency, participatory design, and lived cultural practice [11,22,27] (Figure 2). This concept acknowledges that, the transition to a circular economy in architecture is not just about technical innovation but involves building collective capacities and fostering social infrastructures for sustainable transformation. Circularity can be witnessed in local contexts, where communities take an active role in the decision-making, maintenance, and reimagining their environments. This leads to environmental regeneration, as well as social and cultural resilience.



Figure 2. Conceptual orientation of the Circular Commons. The framework positions circularity at the intersection of technical design practices, cultural/local knowledge systems, and collaborative governance structures, enacted through iterative experiential learning environments (Circular Synergy Workshops).

The Circular Commons Framework puts community involvement, participatory design, and social innovation at the centre of the transition to circularity in architecture [1,20]. Rather than conceptualising circularity as a technical change or material substitution, the framework positions it as a collaborative ongoing process shaped by people and spatial factors. The framework encourages communities, students, and stakeholders to act as co-creators and stewards of shared resources, thereby creating context-sensitive solutions tailored to local needs. The framework encourages systems thinking and interdisciplinary collaboration, emphasising the interconnectedness of buildings and cities with wider social, ecological, and economic networks. In essence, it is a bottom-up, place-based ap-

proach that values social, cultural, and environmental regeneration just as much as vital technical design.

The Circular Commons Framework comprises four core components: Circular Design Practices, Local Knowledge/Cultural Practices, Collaborative Governance, and Circular Synergy Workshops (Figure 3).

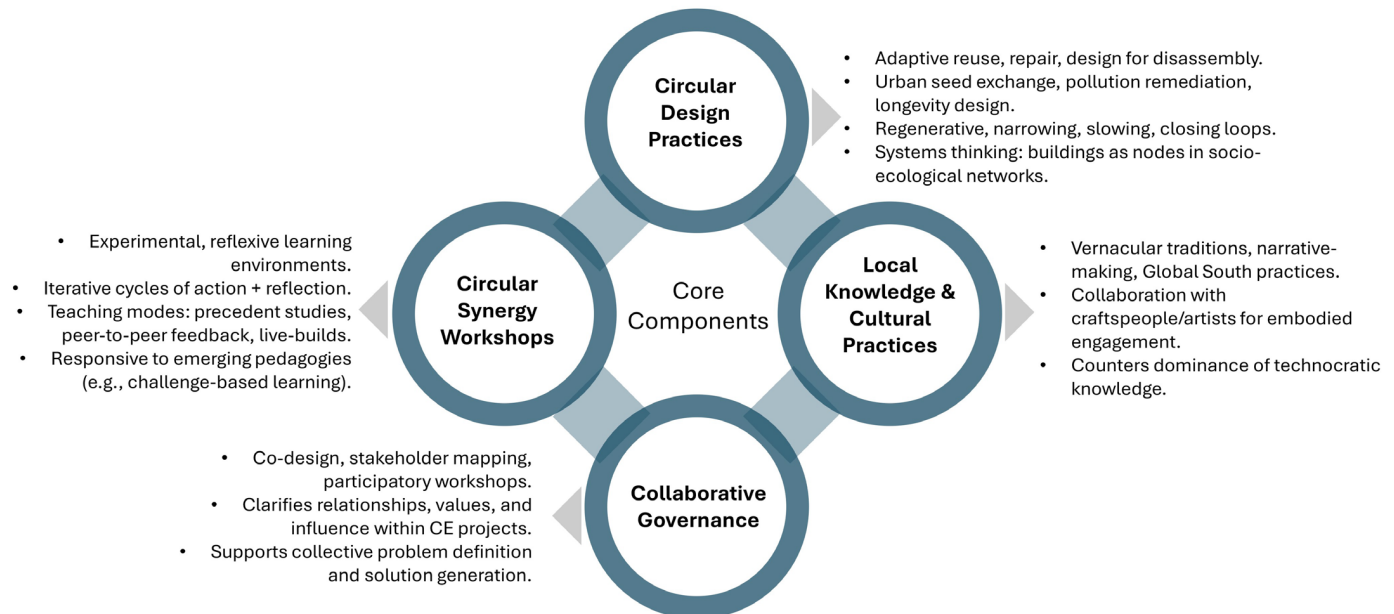


Figure 3. The core components of the Circular Commons Framework demonstrate how empirically grounded elements work interdependently to embed circularity across the technical, cultural, governance, and experiential dimensions of architectural education.

- **Circular Design Practices:** This component incorporates the technical strategies documented across cases, such as adaptive reuse, repair, design for disassembly, material health assessment, and resource efficiency frameworks, including the 10R or 19R hierarchy [16,18,19]. Practices include urban seed exchange, pollution remediation, and design for longevity, with an emphasis on regenerative, narrowing, slowing, and closing resource loops. The application of multi-scalar systems thinking, scaffolded from materials through buildings to neighbourhoods and regions, enables students and practitioners to perceive buildings as integral elements within interconnected social-ecological networks [16,22] (relationships between actors, institutions and practices).
- **Local Knowledge/Cultural Practices:** The framework prioritises vernacular traditions, place-based expertise, and cultural relevance, acknowledging that circularity must be contextually situated rather than universally prescribed. Ulster’s incorporation of Global South precedents demonstrated how resource-constrained contexts foster adaptive strategies offering insights unavailable from Northern European models [16]. This component challenges the dominance of technocratic knowledge, recognising that effective circular transitions require integration of formal technical expertise with vernacular wisdom, cultural values, and community-held knowledge about materials, climate and place [19].
- **Collaborative Governance:** This component establishes structures for co-design, stakeholder mapping, and participatory workshops that empower diverse actors, including students, teachers, local communities, and industry stakeholders. Stakeholder mapping clarifies relationships, values, and potential areas of influence within circular projects, while participatory workshops create spaces for collective problem definition

and solution development [37,38]. This commons-oriented governance positions architects not as autonomous authors but as facilitators coordinating collective action. It accelerates a professional identity shift essential for circular transitions requiring coordinated behaviour across multiple actors and scales.

- **Circular Synergy Workshops:** These workshops are designed as experiential, iterative learning environments where CE principles are enacted through making, testing and reflection. Challenge-based learning formats support student agency and meaningful engagement [39], while peer-to-peer feedback and hands-on projects compound knowledge and foster creativity. These workshops function as laboratories for collective experimentation, bridging technical learning with social collaboration and cultural contextualisation.

6.2. Operationalising the Circular Commons Framework

While the Circular Commons Framework provides a conceptual lens for embedding circular economy (CE) principles in architectural education, its value lies in its practical application. Based on the insights from the literature and comparative case studies, several suggestions are proposed for operationalising this framework across curriculum design, teaching methods, assessment, and enabling conditions (Figure 4).

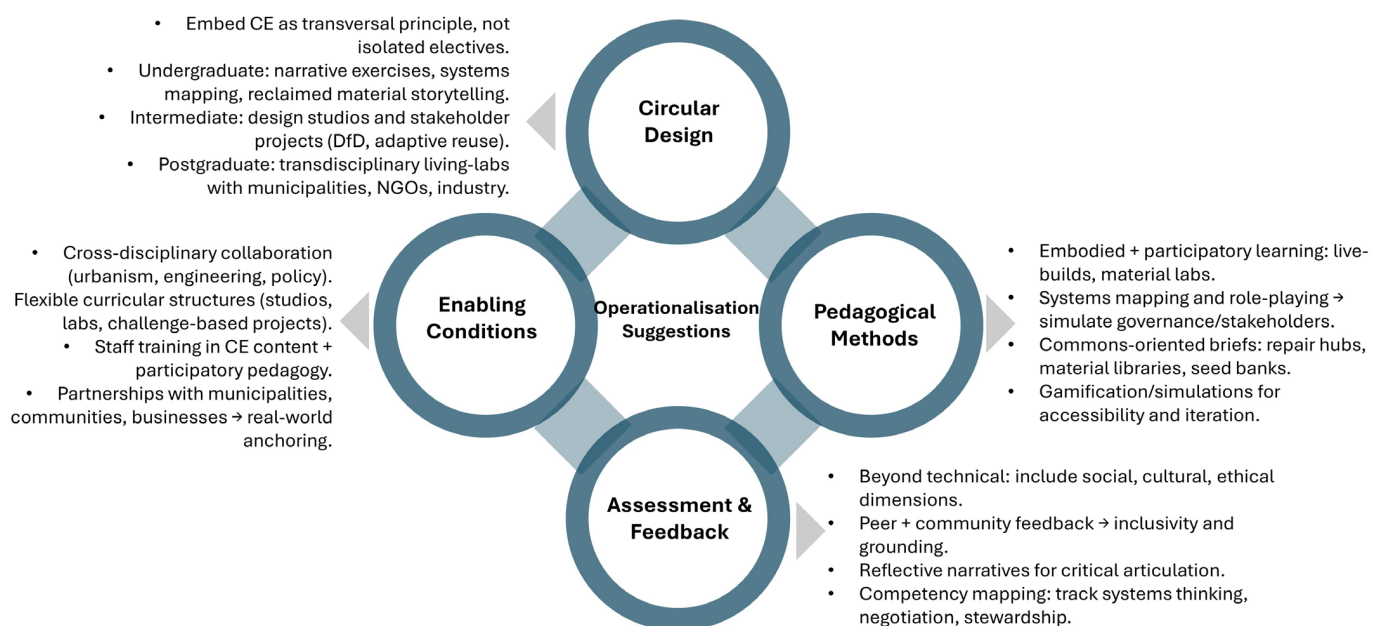


Figure 4. Strategies for operationalising the Circular Commons Framework within the curriculum present an actionable implementation guidance organised across interconnected domains, demonstrating how the framework translates from a conceptual model to a practical pedagogical application in diverse institutional contexts.

- **Curricular Design:** Circularity should be embedded as a transversal principle across all levels of architectural education, rather than an isolated elective, addressing the fragmentation documented in Swedish programmes where CE appeared in fewer than 3% of courses [16]. At the undergraduate level, introduce commons-based thinking through accessible, narrative exercises, analogical reasoning, and small-scale experiments such as systems mapping of neighbourhood waste or storytelling with reclaimed materials. At intermediate levels, expand through design studios and challenge-based projects, applying strategies such as DfD, adaptive reuse, or material passports in collaboration with external stakeholders, as demonstrated by Queen’s multi-scalar studio progression. At the postgraduate level, engage students in transdisciplinary

research or living-lab projects, collaborating with municipalities, NGOs, and industry actors to prototype urban-scale circular interventions, following TU Delft's REPAiR model [8]. This developmental progression builds from foundational literacy through applied practice to strategic intervention capacity.

- **Pedagogical Methods:** To support the framework, pedagogical approaches could prioritise experiential, participatory, and narrative learning as documented across cases. Live-builds and material labs, (Queen's 1:1 reclaimed material construction [15]) allow direct experimentation material cycles and embodied circular thinking. Systems-mapping and role-playing workshops simulate governance processes and stakeholder dynamics as employed in Swedish resource audits and TuDelft stakeholder engagement [16,37,38]. Commons-oriented design briefs encourage students to conceptualise shared infrastructures, such as repair hubs, community material libraries, or seed banks. Additionally, gamified and simulation-based tools facilitate rapid strategy iteration and enhance accessibility of CE principles to learners at all levels [19]. Stakeholder partnerships with municipalities, community groups, and businesses anchor learning in authentic contexts, as demonstrated across all five cases.
- **Assessment and Feedback:** Evaluation mechanisms should address technical competencies alongside social, cultural, and ethical dimensions of circular practice, a gap identified across cases [16,19]. Technical assessment employs quantitative tools: Cairo's circularity calculator for material loop metrics [19], lifecycle analysis evaluations, DfD technical specifications. Social/collaborative assessment utilises peer feedback (Queen's critique structures [16]), stakeholder validation (TU Delft's external partner evaluation [8]), and participatory workshop facilitation rubrics. Integrative assessment combines both through reflective narratives where students articulate how technical decisions connect to social outcomes and cultural contexts (Swedish reflective essays [14]), competency mapping, tracking systems, and negotiation skills alongside material literacy [40], and portfolio development demonstrating progression from technical proficiency through collaborative capacity to strategic circular thinking.
- **Enabling Conditions:** The successful implementation of the Circular Commons Framework relies on supportive institutional structures. Cross-disciplinary collaboration, linking architecture with urbanism, environmental science, engineering, and policy as demonstrated by TU Delft's transdisciplinary studios [8] and Ulster's cross-professional workshops [18], must be facilitated through joint courses, shared studios, or integrated project modules. Flexible curricular structures accommodate workshops, living laboratories, and challenge-based projects requiring institutional willingness to experiment with non-traditional formats and credit allocation. Staff development and training ensure faculty confidence in delivering CE content through participatory methods. External partnerships with municipalities, community groups, and businesses can further anchor student learning in lived contexts while building institutional networks for sustained engagement.

Collectively, these suggestions offer a flexible approach that institutions can tailor to their own resources, contexts, and cultural priorities. By aligning curriculum, pedagogy, and assessment with the values of stewardship and participation, architectural education can move beyond technical training alone and prepare graduates to design and facilitate regenerative, commons-oriented futures.

7. Discussion

The Circular Commons Framework addresses a fundamental tension in CE architectural pedagogy: technical circular strategies have advanced considerably, yet remain disconnected from questions of social equity, cultural agency, and participatory governance

essential for just and viable circular transitions. This discussion extends beyond pedagogical implementation to examine three critical dimensions: first, how repositioning circularity as socio-spatial practice reshapes professional identity, advances social justice and cultural agency, and requires supportive policy and accreditation reforms; second, the framework's limitations including institutional constraints, scalability tensions, and boundary conditions where commons-oriented approaches may prove inappropriate; and third, future research directions necessary to validate the framework across diverse contexts, develop robust assessment infrastructure, address decolonisation questions, and examine economic viability of commons-oriented practice.

7.1. Implications Beyond Pedagogy: Social Justice, Cultural Agency, and Professional Transformation

The Circular Commons Framework's primary contribution lies in repositioning circularity from technical optimisation to a socio-spatial practice that centres social equity, cultural agency, and collective stewardship. This reorientation has profound implications that extend beyond curriculum reform, reshaping how architectural practice engages with communities, validates diverse knowledge systems, and addresses environmental justice through circular transitions.

Material-centric CE approaches risk perpetuating existing inequalities by focusing on resource efficiency without questioning who benefits from circular systems, whose labour enables material recovery, or which communities bear environmental burdens of extraction and waste [31]. The framework's emphasis on collaborative governance addresses these justice dimensions explicitly, requiring students to ask: Who participates in circular decision-making? How are benefits and burdens distributed across stakeholders? Whose neighbourhoods host recycling infrastructure versus green amenities? These questions position circularity as inherently political, not merely technical.

Architectural education cultivating graduates as "equity-minded stewards" (framework objective) prepares professionals capable of designing circular systems that advance rather than undermine social justice. This includes ensuring material recovery infrastructure serves rather than displaces marginalised communities; facilitating community ownership of circular resources (repair hubs, material libraries, shared infrastructure) rather than corporate control; and recognising informal economy workers' knowledge and labour in circular systems. Ulster's engagement with Global South precedents [18] demonstrates how resource-constrained contexts often practice more equitable circularity than affluent Northern models, offering lessons about community-led adaptation and distributed resource governance that challenge conventional CE narratives.

Cultural agency and epistemological pluralism. The framework's local knowledge and cultural practices component challenges architectural education's historic privileging of Western technical expertise over vernacular wisdom, indigenous practices, and place-based traditions [18,41]. By positioning cultural knowledge as essential, not supplementary to circular competency, the framework validates diverse epistemologies: craft knowledge about material durability and repair; cultural practices around resource sharing and collective maintenance; vernacular building techniques adapted to local climates and materials; and community narratives connecting past, present, and future through built heritage.

This epistemological shift has profound implications for professional practice. Architects trained to integrate local knowledge become cultural translators and facilitators rather than external experts imposing universal solutions. They learn to ask: What circular practices already exist in this community? Whose knowledge about materials, climate, and place should inform design? How can formal technical expertise complement rather than replace vernacular wisdom? This approach positions communities as knowledge holders

and co-designers, redistributing power in design processes that have been historically dominated by professional authority [23,24].

Cairo's framework development for African contexts [19] and Ulster's centring of Global South precedents [18] demonstrate that decolonising CE pedagogy requires more than acknowledging non-Western examples; it demands restructuring what counts as legitimate circular knowledge and who is recognised as expert. Graduates prepared for this epistemological pluralism can practice across diverse cultural contexts without imposing homogenised Western CE models.

These social and cultural reorientations necessitate a transformation of professional identity. The framework positions architects as facilitators of collective processes, stewards of shared resources, and connectors across diverse knowledge systems [8,19], roles requiring capacities beyond technical design: skilled facilitation of participatory workshops; cultural sensitivity navigating diverse values and knowledge systems; negotiation across conflicting stakeholder interests; and long-term stewardship thinking beyond project completion. This expanded identity requires recognition in accreditation frameworks currently emphasising technical competencies and design skills [25] but rarely validating facilitation capacity, cultural humility, or stakeholder negotiation as core professional expertise.

Mainstreaming the Circular Commons Framework necessitates advocacy positioning these social and cultural capacities as central, not supplementary to architectural competency. Professional institutes could support this transition by recognising diverse practice models, prioritising community engagement over individual authorship, developing insurance frameworks for participatory approaches involving distributed decision-making, creating career pathways for facilitation-oriented and community-based roles, and establishing mentorship that connects students with practitioners modelling commons-oriented approaches.

Circular transitions embedding social equity and cultural agency require supportive policy: participatory planning frameworks mandating community involvement in circular infrastructure decisions; procurement policies valuing social benefit alongside environmental metrics; building regulations recognising vernacular techniques and incremental adaptation; and ownership structures enabling community control of shared circular resources (land trusts, cooperatives, commons governance models). Architectural education preparing students for this policy landscape must integrate planning law, procurement policy, and commons governance as core content, not peripheral context. Institutions could leverage pedagogical experiments demonstrating socio-cultural circularity as evidence advocating for regulatory reform.

Circular transitions that embed social and cultural dimensions require coordination not only with technical disciplines (such as engineering and planning) but also with social sectors, including community organisers facilitating participatory processes, cultural heritage specialists preserving vernacular knowledge, environmental justice advocates ensuring equitable benefit distribution, and social enterprises developing community-owned circular infrastructure. Educational institutions could model these collaborations through partnerships with community organisations, cultural institutions, and social enterprises, demonstrating that effective circularity requires social infrastructure alongside technical systems.

7.2. Framework Limitations

While grounded in documented practices, the framework faces several limitations constraining its applicability, which can be grouped into institutional and scalability constraints, cultural transferability tensions, professional practice misalignment, and boundary conditions where the framework may prove inappropriate.

The framework assumes capacity for experimentation, cross-disciplinary collaboration, and external partnerships, conditions not universally present. Smaller institutions with limited staff and constrained budgets may struggle to implement living labs or sustained stakeholder workshops. While Cairo's gamification [19] demonstrates lower-resource entry points, full implementation requires investment that many institutions cannot sustain. Swedish experience revealed that even well-resourced universities struggled to mainstream CE beyond electives [14]. Furthermore, evidence comes from small-scale initiatives (Queen's cohort, TU Delft studios [8,16]) that may not scale to large cohorts without losing collaborative intimacy. The framework inadequately addresses how commons-oriented pedagogy scales beyond boutique experiments to mainstream education serving hundreds or thousands of students.

Documented cases serve relatively privileged populations in formal higher education contexts. The framework's emphasis on stakeholder engagement and reflexive practice assumes cultural capital and institutional confidence that may not be universally held. Drawing heavily on Western commons theory [27,31] and European CE discourse [10,13], the framework risks reproducing epistemological hierarchies, despite claims to challenge them. While Ulster's Global South precedents [18] gesture toward decolonisation, deeper engagement with indigenous knowledge systems and non-Western ontologies is required to avoid appropriating non-Western practices as "examples" while maintaining Western theoretical dominance.

The framework cultivates facilitation, negotiation, and collective decision-making capacities that may conflict with professional norms privileging individual authorship and technical expertise [23,25,42]. Architectural practice remains structured around fee-for-service models, legal liability frameworks, and competitive commissions, incentivising efficiency over participation. Graduates may encounter contexts where participatory governance is impractical or where regulations assume individual professional responsibility, which is incompatible with distributed stewardship, risking disillusionment when commons ideals confront market constraints.

Specific contexts may not suit commons-oriented approaches, such as emergency housing that requires rapid deployment, highly technical buildings where expert knowledge necessarily dominates, or contexts where "participation" risks exploiting community labour. The framework must acknowledge that not all practices should be participatory and that commons approaches can become extractive if implemented uncritically.

7.3. Future Research Directions

Several critical questions require sustained research for framework validation and refinement. First, longitudinal assessment and comparative implementation research are essential. Current evidence documents short-term engagement [8,16,19] but lacks longitudinal data tracking whether circular competencies persist into professional practice and how graduates navigate tensions between commons ideals and market realities. Multi-year studies following graduates could identify which framework components prove professionally durable, employing quantitative career tracking and qualitative interviews. The framework also requires testing across diverse contexts: resource-constrained Global South universities, technical colleges, online programmes, and contexts with different cultural approaches to design and community.

Comparative research could identify universally applicable versus context-dependent components while examining how social equity and cultural agency dimensions translate across varied institutional and cultural settings. Additionally, development of a robust assessment infrastructure is needed: validated rubrics for assessing systems thinking, collaborative capacity, cultural sensitivity, and facilitation skills; standardised instruments

measuring circular literacy progression; and portfolio criteria integrating technical proficiency with social and cultural competencies. These tools must balance standardisation, enabling cross-institutional comparison, with flexibility accommodating contextual adaptation, particularly for evaluating social equity outcomes and cultural agency development dimensions, resisting conventional quantitative measurement yet central to the framework's purpose.

Second, questions of decolonising pedagogy and economic viability constitute essential research directions that the framework currently inadequately addresses. Research should document circular practices in vernacular architecture and Global South contexts as epistemological alternatives rather than supplementary precedents [18], critically examining how CE discourse may reproduce colonial extractive logics and investigating how commons-oriented approaches can avoid appropriating indigenous knowledge while genuinely redistributing epistemic authority. Equally critical is exploring the economic viability of circular practice: how prioritising social equity and cultural engagement affects practice economics, what fee structures support participatory processes, how collaborative models distribute financial risk and reward, and what procurement frameworks value social benefit alongside environmental metrics. This economic analysis is essential for determining whether commons-oriented practice can sustain professional livelihoods or remains dependent on subsidised academic or nonprofit contexts, a question fundamental to the framework's real-world applicability beyond educational experimentation.

8. Conclusions

This study examined the ways in which circular economy (CE) principles are integrated in architectural education through analysis of five international cases, revealing both promising pedagogical innovations and persistent limitations. The investigation demonstrated that while technical CE strategies, such as lifecycle analysis, design for disassembly, and material passports, have gained curricular presence, social equity, cultural agency, and participatory governance dimensions remain peripheral or absent. This material-centric bias risks perpetuating the very inequalities that circular transitions aim to address, prioritising resource optimisation over questions of who governs shared resources, whose knowledge is valued in circular decisions, and how benefits and burdens are distributed across communities.

The proposed Circular Commons Framework addresses these gaps by repositioning circularity as a collective, participatory, and socio-spatial practice rather than a technical optimisation exercise and offers a structured, adaptable and scalable model. This framework integrates four interlinked components—Circular Design Practices, Local Knowledge and Cultural Practices, Collaborative Governance, and Circular Synergy Workshops—each grounded in empirical evidence from case analysis. By synthesising technical CE competencies with social sustainability principles, cultural contextualization, and commons theory, the framework offers architectural education a conceptual and operational model for cultivating graduates capable of facilitating equitable, culturally resonant, and institutionally viable circular transitions.

Operationalising this framework requires significant efforts. Its transformative potential extends beyond pedagogical innovation to require systemic institutional change. Moving circularity from elective status to core curricular principle necessitates: accreditation reform recognising facilitation, cultural sensitivity, and stakeholder negotiation as legitimate professional competencies; policy environments supporting participatory planning, community ownership structures, and procurement frameworks valuing social benefit; cross-sectoral collaboration integrating architectural education with community organisations, social enterprises, and cultural institutions; and resource allocation enabling material

labs, living laboratories, and sustained external partnerships. Without these supportive structures, even well-designed pedagogical frameworks risk remaining isolated experiments dependent on individual champions rather than becoming institutionalised practice.

Critical limitations acknowledged in this study include scalability tensions, cultural transferability concerns, professional practice misalignment, and inadequate economic viability analysis. This underscores that the Circular Commons Framework represents an initial theoretical synthesis that requires extensive validation, refinement, and adaptation. Future research must pursue longitudinal studies tracking whether commons-oriented competencies persist into professional practice, comparative implementation across diverse institutional and cultural contexts, development of a robust assessment infrastructure balancing standardisation with contextual flexibility, deeper engagement with non-Western knowledge systems to genuinely decolonise rather than appropriate indigenous circular practices, and economic analysis determining whether commons-oriented practice can sustain professional livelihoods beyond subsidised contexts.

Ultimately, this study positions architectural education at a critical juncture. The circular economy represents not merely technical innovation, but a fundamental reimagining of human relationships with materials, environments, and one another. Architectural education, choosing to embrace this transformation, can cultivate graduates as equity-minded stewards, cultural translators, and facilitators of collective action, thereby contributing to circular transitions that advance rather than undermine social justice. The Circular Commons Framework provides one pathway toward this goal, inviting educators, institutions, professional bodies, and policymakers to collectively develop the pedagogical, institutional, and professional infrastructures necessary for architecture to meaningfully contribute to creating regenerative, commons-oriented futures.

Author Contributions: Conceptualization, M.P.P. and A.M.S.; methodology, M.P.P., A.N.B. and A.M.S.; formal analysis, M.P.P. and A.M.S.; investigation, M.P.P.; resources, M.P.P.; data curation, M.P.P., A.N.B. and C.R.; writing—original draft preparation, M.P.P.; writing—review and editing, M.P.P., A.N.B., C.R. and A.M.S.; visualization, M.P.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not Applicable.

Informed Consent Statement: Not Applicable.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding authors.

Conflicts of Interest: The authors declare no conflicts of interest.

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