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PLANNING FOR CHANGE: A METHODOLOGICAL FRAMEWORK FOR INTEGRATING CIRCULARITY INTO TU DELFT'S FACULTY OF ARCHITECTURE AND THE BUILT ENVIRONMENT'S CURRICULA

A B S T R A C T

This paper introduces a methodological framework to integrate circularity in architectural curricula and the building blocks that led to its conceptualisation. The first block (Part A) examines how complexity has affected learning and architectural education, in particular. The paper departs from the notion that knowledge produces further uncertainty in conditions of critical complexity. Moreover, the highest levels of complexity require the least scientific of approaches. It then examines the main challenges resulting from this shift: one is that learning identifies with individuals' ability to make informed decisions and is now conceptualised as actionable knowledge. Second to that, education should opt for a pedagogy that can support learning through decision making. Architectural education, in particular, should be able to foster a new type of professionalism, where individuals assume accountability for their design decisions that extends beyond the aesthetic realm. But what can drive curricula to become more responsive to the current environmental, social, and political realities? The second block (Part B) looks into the issue of circularity. It examines its relevance to architectural education for its potential to function both as an operational scheme as well as a value system. Furthermore, being a concept in the making, circularity can benefit from academic research but can also support a pedagogy that focuses on helping students learn how to learn. The proposed methodological framework (Part C) builds on these two blocks and on the faculty's research on circularity to develop a scheme of what constitutes content for teaching circularity, how the goals for integrating it into the curricula can be formulated, and what type of pedagogy is suited to support the integration.

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INTRODUCTION

The built environment is largely responsible for raw materials exploitation, waste production, and greenhouse emissions.[1] Globally, more people live in urban than in rural areas, and by 2050, two-thirds of the population will be living in cities.[2] Current architectural approaches cannot affect the change required to tackle these challenges.[3] Confronted with complexity and entrapped in knowledge fragmentation as well as its own disciplinary limitations,[4] architecture must reconsider its relevance and re-examine its ethics for 'protecting the Earth.'[5] Rethinking the traditional subjects and clarifying what is particular to the discipline[6] is a necessity that significantly affects architects' training. The need for a new type of education is emerging: an education that enables learners to fully engage with critical realities[7] by developing human qualities such as criticality and resilience, which, in turn, provide them with the capacity to think and act purposively despite complexity.[8]

This paper introduces a methodological framework to integrate circularity into architectural curricula as well the pedagogical implications the framework entails. The framework is grounded on the belief that architects' sense of accountability needs to be extended beyond the aesthetic realm while acknowledging that the world is inherently complex. However, here lies a strange paradox which has been one of the main challenges behind the framework's conceptualisation: if, in times of critical complexity, the knowing-of-the-world can only be imperfect,[9] then where can this extended accountability draw its relevance from?

The authors argue that one implication of critical complexity is that learning is now situated in making decisions.[10] This requires that individuals must prioritise the information at hand and make distinctions. Another notion that emerges across the different accounts of complexity theory is that the highest levels of complexity require the least scientific approaches. Basarab Nicolescu calls this a new spirituality;[11] for others, it simply translates to revisiting humanity's values discussion and setting a new ethical background against which design decisions can be made.

It is here that circularity enters the discourse and why it becomes relevant in architectural education; its power lies in its capacity to organise the socio-technical while also claiming a change of ethics. Moreover, as circularity is a gradually evolving phenomenon and therefore still indeterminate, its integration into architectural curricula constitutes a mutually beneficial strategy. Circularity can feed on academic research, and, in return, architectural pedagogy can benefit from experimenting on how to teach students to learn in conditions of critical complexity.

The first part of the paper examines how the world's complexity and individuals' growing sense of uncertainty have affected knowledge creation. It also looks into how emerging learning theories and the latest pedagogies have adjusted in order to explain and address the impact of complexity in teaching and learning processes. In the design methods movement and – by extension – design education, complexity can be traced back to the 1960s and the multiple ways it challenges humanity with the current environmental crisis and thus climate change and the depletion of resources. The second part of the paper is dedicated to circularity and its relevancy for architectural education. In the third and final part, the paper builds on these blocks to create a new methodological framework along with the reasoning behind its creation and its projected implications for pedagogy. Finally, a discussion section identifies the barriers and limitations of the proposed methodology and critically reflects on how circularity can ultimately creatively reshuffle educational priorities.

PART A - Teaching and Learning

1. Teaching And Learning In Times Of Complexity And Uncertainty

> The world is not all in, it is in the making.[12]
> We change the world and the world changes us.[13]

In popular parlance, complexity is often used to describe situations of controversy, ambiguity or multiplicity when the new worlds that emerge are clashing with the existing order.[14] Although interest in complexity can be traced as far back as the first half of the twentieth century,[15] a more systematic understanding of complexity was established by the 1984 Santa Fe Institute Workshops, when the term was first used to define systems with 'a very large number of interactions and feedbacks, inside which processes are very difficult to predict and control take place.'[16]

Edgar Morin further distinguished between two types of complexity: what he calls restrictive (or theory of everything) and generalised (or critical): whilst the first encompasses chaos, disorder, and uncertainty in the most common sense and use of the word, it remains within the epistemology of classical science. The latter, however, requires an epistemological rethinking, a new paradigm for creating knowledge.[17] Critical complexity resists scientific reductionism, determinism or holism of systems theory because it focuses on understanding the intricate interrelations between the whole and the parts where only certain aspects can be understood at a time.[18] Therefore, descriptions of complex systems cause further distortions, making our models imperfect renditions that introduce further uncertainties.[19]

In a surprisingly similar line of thought, Roland Barnett makes a parallel claim from an educational perspective: if the knowing-of-the-world produces further uncertainty, education should not support learners to acquire knowledge or skills, but instead help them create a self that is adequate to an uncertain world.[20]

1.1. Learning theories and pedagogies for complexity: from systems to networks

Complexity theory and its contribution to epistemology did not give rise to a specific learning theory or pedagogy right away. In the late 1980s, around the time complexity theory was developing, the prevailing learning theories of 'Communities of Practice' (CoP)[21] or 'Situated Learning'[22] tried to expand the idea of social learning as a system with an identity of its own, a developing structure as well as self-organisation and meaning-making processes. Similarly, the 'Communities of Inquiry' (CoI) learning theory looked closer to social learning in the framework of online communication and exchange. It perceived it as a system with closed boundaries that provided 'order, heuristic understanding, and a methodology for studying the potential and effectiveness of computer conferencing.'[23]

Even though limited to restricted complexity, both of these theories contributed greatly to pedagogy: CoI promoted autonomous learning that flourished in later theories like Heutagogy[24] and self-regulated learning.[25] CoP, on the other hand, – by nature outside formal educational organisations – promoted the importance of informal learning[26] that later became the prevailing concept in the pedagogy of virtual learning communities.

Critical complexity manifested as a core learning principle only twenty years later with connectivism: the theory poses that learning occurs within 'nebulous environments of shifting core elements that are not under the control of the individual.'[27] Learning, in this case, is identified as 'actionable knowledge' and is described by the ability to make decisions by drawing distinctions between important and unimportant information and by recognising when new information alters the landscape.[28]

In connectivism, the dominant metaphor is that of networks; systems that are intentionally open to their environment, can classify their own interaction with it, and change their structure accordingly.[29] Integration of connectivism in pedagogy, however, has been characteristically slow.[30] What makes connectivism relevant for critical complexity is what makes it controversial in an academic setting: its distributed, destabilising nature and informality clashes with the formal, hierarchical order of academic institutions as well as established forms of education[31] such as the design studio model in architecture – still the main vehicle for learning in the discipline.

2. Complexity In Architectural Design Methods And Education

2.1. How complexity has been confronted by design methods and design education

Complexity challenges designers and engineers, who are at the forefront of change. It has been central to this debate ever since the launch of design methodology as a research topic in 1962 at the London Conference. In his book 'Notes on the Synthesis of Form' published as early as 1973, Christopher Alexander, one of the founding members of the design methods movement, stated that 'more and more problems are reaching insoluble levels of complexity.[32]

Until the 1980s, design methodology – and by extension design education – systematically tried to tackle world complexity by exploring its synergies with science to gain validity and relevance.[33] Influenced by modernity and analytical thinking, complexity was to be tamed by breaking a problem down into smaller, manageable parts. Knowledge creation followed the analysis-synthesis model,[34] matching systematic observation and inductive reasoning in the analytical phase, and subjective and deductive reasoning in the creative phase.[35]

Theoretical constructs, such as the distinction between 'tame and wicked' design problems formulated by Horst Rittel and Melvin Weber in the early 1970s, established that while science needs methods with replicable results, design does not. Therefore the scientific method was inadequate for resolving complex design problems which are unique by nature.[36] Design methods theorists' original fascination for scientific certainty gradually succumbed to the appeal of systems theory and cybernetics. Following the interdisciplinarity paradigm of systems theory, design methods theorists extended their interest in the neighbouring disciplines, especially art and the social sciences, as the study of design itself grew to become an independent discipline. Research became predominantly perceived as cross-disciplinary experimentation, and theoretical courses proliferated.

As a result, in the years that followed, architecture largely shifted its focus from the end product to the design processes.[37] Its theoretical base grew significantly; however, at the expense of its technical and operational capacity.[38] The advent of digital technologies and computer-aided design in the early 1990s announced 'a massive, technology-driven change' but even so, in this initial stage, design remained largely dependent on the preceding theoretical discourse.[39]

Meanwhile, complexity gave rise to a new type of architecture: non-linear architecture.[40] Architects set out to tame complexity, this time, by means of computation. However, while the tools developed for form-generation, structural and environmental analysis, simulation and optimisation were excellent, this kind of architecture failed to acknowledge social, political, and economic qualities and conditions. It was highly criticised both for its insensitivity to local contexts as well as its reliance on bespoke production chains.[41]

2.2. Complexity unresolved: the future that is now

Complex geometries ultimately gave rise to expressive, iconic architecture made possible by the market boom of the early 2000s.[42] However, these signature buildings, 'sculpturally assertive but signifying nothing but the vanities of self-expression and the vacuous pursuit of novelty,'[43] further strengthened the predominant notion of continuous growth and neoliberal economics as well as the modernist tradition of the individual architect, while severely undermining the criticality of climate and material emergencies.[44]

Environmental concerns had been expressed as early as the 1960s, focusing on the idea of waste as a negative force: however, the notion of sustainable development that flourished in the late 1980s (Brundtland report was published in 1987) gave way to new ideas about waste management with a more positive take.[45] Although the complexity of the debate increased in the following years, clear answers could still not be obtained.[46] Mainstream architecture never engaged with the premise of sustainability; buildings continued to be produced without any regard for their environmental impact, while any emergent form of architecture that showed a concern for the environment was dismissed as ugly, condemning sustainability as an aesthetically irrelevant issue.[47]

Gaver et al. suggest that design may only be aesthetically accountable, not epistemologically.[48] Meaning that maybe designers do not have to justify their methods as scientists do. But what about their accountability in acknowledging the critical issues of their time and acting accordingly? Contemporary challenges identified include, but are not limited to, preserving biodiversity, identifying transparent and egalitarian forms of governance and economies that are sufficient and accountable, and managing production and consumption habits within the planetary limits.[49] According to Jeremy Till,[50] current approaches are incapable of affecting the change required for current emergencies. Therefore one should break away from architecture's attraction to certain systems and values. If the only certainty we can rely on is that our current ways of doing and thinking about architecture can no longer be sustained, then we need to 'actively start designing the conceptual spaces we depend on as we design.'[51]

From here onwards, designers mainly appeal to two domains to resolve complex issues: either the premise of technology or the more challenging – and perhaps even more controversial – values discussion. On the one hand, the 'what' and the ‘why’ of architecture are expected to arise from the wide dissemination of digital fabrication techniques and the power of programming. Philippe Morel, co-founder of EZCT Architecture & Design Research, argues that we now need to address the question of architecture beyond mimesis and beyond humanly thinkable thoughts where computation takes over all aspects of everyday life (highlighting is ours).[52] The second line of thinking follows Nicolescu’s[53] quest for a new spirituality: counteracting the Anthropocene and resisting the dynamics and effects of neoliberal capitalism is to be found in the subjective dimensions of psychology and culture,[54] and gearing towards an architecture of caring, ‘not just for the built environment, but for the whole planet including its human labour force.’[55] Emergent terms like ‘sharing economy’ and ‘degrowth’ have been introduced to propagate systemic change by downscaling production, either by promoting peer-to-peer consumption and platform economy in the first case or through community-based forms of production, exchange, and consumption in the latter.[56]

Needless to say, a certain tension exists between the two directions: in the first case, information technology and open knowledge are expected to democratise production, and it is computation and auto-construction that will provide the basis for the social aspect to evolve.[57] Today’s non-standard robots, says Mario Carpo, will create the automated version of the pre-industrial artisan, and the social import of this revolution will be unleashed almost accidentally.[58] In the second case, architectural positivism is renounced altogether along with the whole growth doctrine: complex issues such as climate change cannot be solved by ecology and technology nor by any means that originate in the current regime, for that matter.[59] Rather, it takes a different paradigm altogether and a complete restructuring of our being in the world if we are to conceptualise a sustainable future, that is to find the symbolic language and the new spirituality Nicolescu is arguing for.[60]

Institutions are required to think afresh about how they can participate in rethinking the responsiveness and relevance of their curriculum and mode of pedagogy against current environmental, social, and political realities.[61] So, how should architectural education respond? We argue that its role is to continue developing those concepts that can help model reality while streamlining the preferred, the imaginary and the visionary. And this is why circularity has become a central theme in our research: situated at the intersection of the two aforementioned trends, it constitutes both an operational and a value system. The following sections attempt to provide a brief profile of what circularity is, why it is relevant today in architectural studies, and how it can become instrumental in dealing with complexity and, therefore, essential in architectural education.

PART B - Circularity

3. The Advent Of Circular Economy And The Circular Built Environment

The notion of *circular economy* (CE) as an alternative to the linear take, make, waste model first appeared in the early 1970s and was further developed in later years, amongst other factors driven by increasing energy prices and high unemployment.[62] CE is closely connected to different schools of thought such as Regenerative Design; Performance Economy; Cradle to Cradle; Industrial Ecology and Biomimicry.[63] CE developed on five principles advocated by the aforementioned schools of thought: designing out waste; building resilience through diversity; relying on energy from renewable resources; thinking in systems; and waste being food.[64] The circularity component of CE particularly pertains to material use, aiming to narrow material flows (use less), slow material flows (use longer), and close material flows (use again)[65] while striving for systemic value retention rather than value destruction.

Circularity has gained increasing relevance since 2015 when the EU adopted the first CE Action Plan.[66] And after successfully implementing a series of targeted actions,[67] the EU launched a second Action Plan in March 2020 that builds on the knowledge and know-how produced in the first, while continuing to refine the concepts introduced half a decade earlier. What is more, the EU increasingly focuses on policies that bond circularity with energy consumption, as the recent launching of the EU Green Deal attests. 'Enacted globally,' the authors of the latest version of The Circularity Gap Report claim, 'a CE can close the Emissions Gap,' leading us to a below 2-degree world by 2032.[68] The same report further accentuates the need to apply circular strategies at 'the intersection of materials and emissions hotspots.'[69]

CE has been extensively scrutinised for being too vague, fragmented, dependent on other scientific concepts, and for downsizing conflicts, trade-offs, or the fact that even cyclical systems require energy and produce waste.[70] Moreover, CE is not politically neutral, meaning that circular strategies - such as repair and remanufacturing - may overlook potentially transformative, political, and future-oriented roles based on integrity, care, and legibility values rather than merely new forms of capitalist commodification.[71]

Implications of CE for the built environment remain underexplored. In this regard, the Circular Built Environment (CBE) Hub of the Faculty of Architecture and the Built Environment of TU Delft has systematically undertaken research projects to uncover how the built environment affects and is affected by circularity. Research findings have culminated in a definition that reads as follows:

> The Circular Built Environment (CBE) is a system designed for closing resource loops at different spatial-temporal levels by transitioning cultural, environmental, economic & social values towards a sustainable way of living (thus enabling society to live within the planetary boundaries).[72]

The definition bridges the two ends of the discourse examined in the previous section. On the one hand, it builds on the socio-technical aspects of CBE to conceptualise it as a designed system, where technology holds a key role. But what it also suggests is that CBE requires a transition of values against which the use of technology can be put into context. In this light, circularity is bound to the inherent complexity of architectural practices that enmesh 'cognitive, cultural and material elements.'[73]

4. Why Is Circularity Relevant In Architectural Education?

Below, the relevance of circularity in architectural education is discussed both as an organising principle that can be used to read and manage critical complexity in the built environment as well as for its inherent values. Moreover, the pedagogical potential of integrating into curricula is assessed.

4.1. General appeal

The most obvious argument would be that circularity is being widely adopted and promoted as a key strategical approach in both top-down and bottom-up initiatives. Arguably, grassroots initiatives have paved the way for a broad societal appeal, including support from industrial and business perspectives. Not only, but particularly in the Netherlands, this societal support was rather quickly accompanied by the establishment of top-down regulatory frameworks. As outlined above, policies to support circularity have come into action at the EU level. Circularity is thus a phenomenon relevant to present times.

4.2. Necessity

Another critical motive for integrating circularity in education is dire; in light of 'planetary boundaries' awareness,[74] including urgencies around climate change and the depletion of resources, future generations of students need to be equipped with the necessary tools to facilitate or carry out the required transition to avoid, mitigate or reverse environmental tipping points. Since circularity is highly relevant in the built environment,[75] it is also relevant to the criticality and the challenges of our times.

4.3. Dual character

Another characteristic of circularity is its capacity to manifest both as an operational scheme and a value system. It is pragmatic as much as it is idealistic. Take the R strategies for example: on the one hand, they propose concrete ways of either closing, slowing or even narrowing material loops. On the other, inherent to these strategies are the values of caring and sharing. These are expressed by either prolonging a material's life cycle through repair or manufacture, or by intensifying a material's use through rethink. Or in the more extreme cases, by even refusing to make use of a given material in the first place.

4.4. Social prevalence

A greater opportunity lies in the fact that circularity forges the recalibration of society. The mentality change it requires affects and is affected by a wide range of actors and individuals in different capacities in the built environment. Integrating circularity in architectural education can therefore ensure a more socially inclusive perspective.[76] In this case, circularity is relevant for its capacity to penetrate society and for becoming owned by a larger audience.

4.5. Circularity as a designed system

Wide collaboration and exchange between owners and stakeholders require new types of synergies. Therefore, systemic processes related to the built environment need to be reconceptualised and redesigned: from extraction, manufacturing, construction, and maintenance to deconstruction and reverse supply chain logistics. While engineers are 'part and parcel of the hardness of socio-technical landscapes,'[77] the architect's role, says Andre Jaque, 'is to expose the socio-technological apparatus to mobilise and rearticulate the elements at play.'[78] Transitioning to a circular built environment thus requires architects to have the critical capacity not only to identify all actors involved and/or affected but to also design their interactions.

4.6. Ethical basis for designers

In an interview with Hans Ulrich Obrist, Jaque also claimed that 'differences are constructed by the way they interact.'[79] This would ultimately generate a way of thinking ethics in architecture in which the authors' intentions are less important than the result of their intentions as the process is socialised.[80] Design value is thus directly related to the relevance it acquires in the social realm.[81] The debate is not new, of course. In a paper written in 1971, Thomas A. Markus claims that none of the design models produced in his time had focused on the social and political status of the designer. Thus, all failed at relating design systems to other social and political actions.[82] Markus went on to describe three potential roles for future designers: he argued that they could either increase the emphasis on their expert role, adopt a sympathetic stance to the so-called participatory design processes, or reject both solutions and look for ‘a real transfer of power in design decisions.’[83] All three roles depend on how designers ultimately place themselves in the broad spectrum between ‘environmental control and all other control in the system.’[84] Circularity challenges architects’ ethical framework by confronting them with this decision.

4.7. Circularity indeterminacy

Circularity, being in its infancy, enters education with many uncertainties. Architects still lack the tools necessary to evaluate circular endeavours; they are still uncertain as to which value models are adequate. An accurate materialisation of this principle or an upscaling strategy remains at large despite the need for modularity having been recognised.[85] This is exactly what makes circularity relevant in academia. Industry and practice may have picked up on the phenomenon and may have already started producing tangible manifestations of how it can be applied; however, there is a need of making sense of what already exists and to what extent it can be generalisable. At this point, academia can be conceptualised as a platform that allows continuous feedback looping within the knowledge creation system.

4.8. Learning to learn

Because circularity remains uncharted territory, it can be instrumental in a pedagogy whose values rely on helping students acquire the skills needed to survive the uncertain world, Barnett described.[86] In this regard, the role of education becomes that of developing ways to teach individuals not only particular concepts or skills but also learning as such. Teaching about circularity will then enable individuals to develop their own toolbox for understanding and managing its complexity, making connections and decisions and most importantly, acting on them in order to learn.

5. What is the current landscape of architectural education in relation to circularity?

Whilst various aspects of circularity are widely discussed in current academic research, there is only a nascent body of literature for teaching circularity in higher education institutions. It is mostly focused on individual case studies at course level, students’ assessment, and feedback on the process.[87] It is most notable that, in most research papers on architectural education, circularity appears as a sub-domain within the larger domain of sustainability and rarely as an independent concept. Knowledge of CE and the ability to apply its principles, however, must be embedded in the curriculum so that they become integral to design practice.[88]

A recent study focusing on integrating sustainability in Asian architectural schools revealed that the concept manifests mainly in (building) technology courses and much less in theory courses or design studios.[89] Some of the main

difficulties of integrating circularity in design studios across levels are attributed to its systemic character and the fact that it extends into knowledge domains that, whilst being very relative to circularity, are not traditionally related to design.[90]

Another study commissioned by the Ellen MacArthur Foundation[91] found that at least 138 higher education institutions have learning offerings in CE and that TU Delft scores the highest on the list. Nevertheless, considering the fragmented landscape of practices in architectural circularity education, the next section is dedicated to the possibilities of creating a methodology for teaching circularity both in terms of content as well as pedagogy. The approach is being developed by a team of researchers of the Faculty of Architecture and the Built Environment at TU Delft.

PART C - A Methodology

6. Methodology: How Does One Integrate Circularity In Education?

Summing up what was discussed thus far, there are at least five key points to consider for developing a methodology that integrates circularity in architectural education curricula:

> 1. We are at a point where knowledge produces further uncertainty, and thus, we need to come to terms with the notion that any attempt to describe our reality, let alone manage it, will always be lacking;
> 2. Learning can be considered as actionable knowledge, as in making decisions/choices in the nebulous, unstable environments we encounter;
> 3. Science has not been able to fully address the complexity of design issues, and a need to establish a new values system is emerging;
> 4. Designers' aesthetic accountability and fixation on form obscures the critical imperative of their accountability in addressing the complexity of the problems of our times;
> 5. Despite being complex and currently underexplored, the relevance of circularity adds value to architectural education by providing a way of organising the socio-technical while also claiming different ethics.

A methodology for integrating circularity in architectural education is founded upon these points and will be further presented and explained in this section of the paper. It is essential to note that it is not directed towards a specific course; rather, it addresses change at the curriculum level.

6.1. Contextualising content by what we know: the 'scales to aspects' model

So, how does one plan education knowing that any given concept cannot be fully represented, let alone a concept that is still in the making? We suggest that this happens by contextualising the concept within a space that includes what is currently known about it but also has the ability to transcend the limits of these notions.

Returning to Morin's taxonomy of restrictive and generalised complexity, Woermann argues that, in both cases, the necessary condition for creating meaning is modelling.[92] But while modelling remains descriptive for the first category, it involves a normative component for the latter as we must make choices, judgements, and assumptions as well as recognise that our modelling strategy represents one choice among many.[93]

It is our understanding that circularity - as an evolving knowledge domain – is an issue of generalised complexity (and therefore, in Barnett's terms, it is not only unknown but, at times, even indescribable). To model it, we adopted CBE Hub's 'Scales to Aspects' model as our canvas for carrying out research and contextualising research findings.[94] The CBE Hub model's primary function is to relate the concept of circularity to the built environment; it does so by distributing its entanglement to six distinct scales and an equal number of aspects.[95] Figure 1 represents an abstract representation of this selection. Despite its apparent simplicity, the model poses that in a CBE all scales are interconnected and therefore cannot be considered in isolation, while the outer ring of aspects suggests at least six topics identified as conditioning the scale interdependencies.

The model introduces a thinking-in-systems framework (and not a cognitive scheme) that is neither finite nor exhaustive; it simply states that any meaning-creation process regarding the CBE is necessarily mediated by the interpretative duo of scales and aspects onto which multiple combinations and interpretations are possible. Complexity theory, says Mark Mason, 'seeks the sources of and reasons for change in the dynamic complexity of interactions among elements or agents that constitute a particular environment,' and he argues that education research should therefore:

> […] move away from causal models to modelling the specific, local linkages that actually interconnect actors, practices, and events across multiple levels of organisation; and away from single interventions and simplistic solutions to the recognition of the need for coordinated changes throughout the system and to its constraining and enabling contexts and resources.[96]

Furthermore, the model pertains to a moment in time in the process of addressing circularity in the built environment: its components depend on the temporal occurrence in which a reading is attempted and are therefore likely to change. Circularity evolves, and so does our understanding of it.[97] Acknowledging and allowing for change is a fundamental principle for conceptualising concepts in times of complexity: the openness and flexibility of the 'Scales to Aspects'

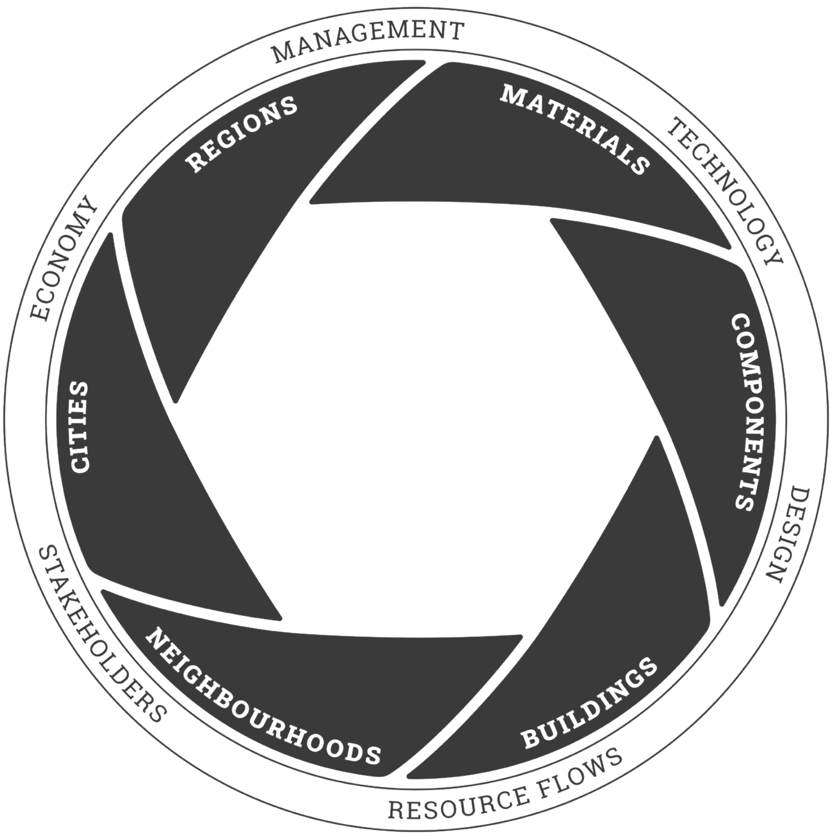

Fig. 1. The "Scales to Aspects" model

model relates to the shifting ontologies of the network metaphor of connectivism as well as the principle of reciprocity, introduced by Kirchherr & Piscicelli.[98] While for the two authors reciprocity is limited to the ability of learners to reiterate the content and modes of delivery of a course on circularity, in this case, reciprocity is scaled up and used to account for learners' ability to sustain, enrich or question the dynamic equilibrium this model proposes.

6.2. The circular learning objectives (CLO) list

Based on the 'Scales to Aspects' model, a new conceptualisation of how circularity can be integrated into architectural curricula emerged that allowed to create what is now addressed as the list of Circular Learning Objectives (CLO) (Figure 2). The list was devised in early 2021 and has since been used in guiding discussions related to how circularity should be integrated into the faculty's curricula.

Barnett was quoted earlier claiming that complexity and uncertainty require more than knowledge or skills; they require a pedagogy that enables individuals to prosper in uncertainty. Despite following the classical taxonomy of knowledge, skills, and competencies/attitudes, the CLO list does not claim to be exhaustive of what a curriculum should entail. Rather, it seeks to establish a coherent narrative and relatedness to the research implemented thus far as expressed by the 'Scales to Aspects7' model as well as to the system the faculty currently employs to efficiently channel its guiding principles and vision throughout its study programs.

6.3. It all starts with systems thinking

The most critical aspect of the CLO list lies in the introduction of the first two blocks: Context and Basic Knowledge. Context allows for circularity to be introduced as a fluctuating concept dependent on a larger context within which its presence marks a value. The teaching of systems theory and complexity theory introduced in this block informs learners about what the systemic change circularity calls for means. The relation of circularity to sustainability is also included here to relate the two notions and to challenge learners to relate to them. Finally, the social relevance of circularity and its potential in contributing to the establishment of new design ethics need to be discussed at this preliminary stage. This last part relates to points 3-4-5 to support learners in conceptualising design as a political act and in assuming accountability for their own design decisions.

The Basic Knowledge block, on the other hand, offers the basis for a shared understanding between learners. It features a series of terms that have a proven

		CIRCULAR LEARNING OBJECTIVES		
		KNOWLEDGE	SKILLS	COMPETENCES/ATTITUDE
BLOCK 1	CONTEXT	systems theory/ complexity theory/ holistic theory: contextualise circularity as a key concept of the design process in continuous interaction with other methods and tools	to engage in design/research work related to circularity/ handling (complex) problems/ learning to work with the context	be able to identify/acknowledge the relevance of circularity in design discourse
		relation of circularity to sustainability		be able to distinguish between sutainabilty in relation to circularity/ position circularity
		the ethical/political position/ circularity as a cultural shift; a new mentality/ design as decision making across multiple dimensions of accountability		be able to support conscious decisions/ endorse systems thinking
BLOCK 2	BASIC KNOWLEDGE	basic terminology		be able to identify what distinguishes a circular approach
		basic definitions		be able to tell the difference between the different terms and what they stand for
		circular materials: biological, technical		to be able to understand and manage the different possibilities/ to choose the most relevant material per case
		basic strategies: R strategies; Smart Manufacturing/ Extended Life Span/ End of Service/ End of life; Slowing-Narrowing-Closing the loops		be able to integrate the terminology in their own argumentation
		basic design approaches: design for disassembly; design for reassembly; design for adaptability; regenerative design	to design for disassembly/reassembly for their own design work	be able to make circular choices/endorse circular principles in terms of materials; design methods such as design for disassembly
			to design for adaptability for their own design work	be able to recognize how circularity affects their own design decisions
			to use regenerative design for their own design work	be able to communicate circularity verbally and designerly
LEVEL ONE: DISCIPLINARY	APPLIED KNOWLEDGE	scales: material; product; building; neighborhood; city; region	to contextualise/adapt design decisions according to scale	be able to identify the interdependency between scales
		aspects: design; technology; flows-resources; society-stakeholders; economy; management	to analyse and highlight further dependencies	be able to identify the plurality of actors affecting circular decisions
		case studies; examples from all scales and circular manifestations	reproduce design details/ methods	be able to recognize/illustrate/represent/reconstruct/ model/ embody how circularity affects design decisions in examples/ case studies
			represent circular approaches in a designerly way	be able to recognize/ /illustrate/represent/reconstruct/model the impact of circular decisions
LEVEL TWO: INTERDISCIPLINARY	CRITICAL KNOWLEDGE	deepening of systems theory/ complexity theory/ holistic theory/ interdependencies	to frame/reframe design approaches in order to optimize circular characteristics and tackle foreseeable limitations and barriers via research/design	be able to anticipate/recognize/detect intricate connections; complexity and diversity
		detailed overview of critical theories/practices on circularity: systems and services, policies and regulations		be able to select/apply the right circular approach per case
		critical thinking about limitations and barriers/ optimization tools		be able to anticipate/recognize/detect connections and barriers and to ultimately highlight/resolve them respectively
		assessment methods for circulartiy (LCA-LCC-MCI etc)		be able to compare info-data/ make informed decisions per project
		materials/ components/ construction/ spatial framework	to design innovative ways/methods/tools for material use	be able to make informed decisions via all scales/ contextualize
LEVEL THREE: TRANDISCIPLINARY	GENERATION OF (NEW) KNOWLEDGE	synthesis of all of the above+ current ongoing research/ systematic practice+experimentation across different contexts and disciplines and beyond disciplines/ assocative thinking/ network thinking	to contribute to existing circular approaches through further design/research using existing methods or hybrid/new ones	be able to create impact
			to experiment with and embody circular thinking in new design challenges	
			to determine/design/formulate innovative courses of action/ to expand/explore/elaborate hybrid forms and collaborations/ or optimise existing ones	be able to increase impact
			to experiment and to develop/formulate new research/design tools and methods in developing circular plans/ or optimise existing ones	be able to facilitate/enable and further communicate/propagate circular thinking through tangible ways
			to develop case to case contextualised/ tailor made circular solutions/ to practically implement circular design approaches	be able to map/ detect/ recognize opportunities for circularity in different contexts
			to use the existing and to further develop research/design tools and methods for evaluating circular actions	be able to measure circular impact
				be able to evaluate circular impact
			to consistently/ continuously embed circularity in design and research in a widely communicable way	be able to generalise research results/ findings about circularity endeavors/ feed the two precedent categories and ongoing research

Fig. 2. The CLO list

value in representing circularity verbally or designerly. The main role of this block lies in facilitating communication, where different approaches can be distinguished and thus design decisions can be based upon.

6.4. Sharing what we know and how we do it

The list further distinguishes between three learning approaches: Level One represents the disciplinary approach and focuses on circularity as it currently manifests within the design discipline. This level of learning examines

circularity as an organising principle of design and refers mostly to the model's configuration of the scales' interdependency. Knowledge and skills of that level are related to getting learners acquainted with the most prevalent design approaches and engaging them in circularity in a designerly way. We call this knowledge *applied*. Ultimately, learners should be able to distinguish between the scales and identify their interdependencies, acknowledge the existence of aspects (outer ring) as to what conditions the scales' interdependency, and recognise how circularity specifically affects design decisions.

Level Two represents the interdisciplinary approach: it looks more closely into the synergies that circularity stirs between the design discipline and other affiliated disciplines (mostly what the model describes as aspects), such as economy, management, social studies, as these have already been identified. We call this knowledge critical. It pertains to an attitude of recognising the intricate relations between disciplines and their limitations as well as coming up with ways and tools of making informed decisions.

Level Three represents transdisciplinary learning. Bararab Nicolescu calls this space 'beyond the disciplines.'[99] Neri Oxman, using the Krebs Cycle of Creativity, follows knowledge creation as the sequence between the four domains of Art, Science, Design, and Engineering where everything starts 'when new perceptions inspire new scientific explorations.'[100] Transdisciplinarity is intended here as the ability to work in the space in between the well-defined disciplines to explore new ways of thinking; the combination of 'a scientific-technical problem-solving competence with an understanding of the problems that need to be solved; a mixing of scientific knowledge and technical skills with what might be termed cultural empathy' otherwise referred to as hybrid imagination.[101] This approach alludes to coming up with novel ways of increasing the impact of circularity as well the recognising opportunities for circularity to benefit from different contexts. We call this knowledge *new*.

There is neither a strict division between the three levels nor does this listing necessarily represent a temporal sequence; it simply represents different approaches in understanding and managing how circularity challenges design thinking. Thus, new knowledge can always be created within any of the three approaches. Furthermore, the scheme does not imply a causal, deterministic relation between knowledge, skills, and attitude: the system is not closed. Therefore, what comprises knowledge and skills is not finite. It is itself subject to change, should new understandings or perceptions emerge.

6.5. Pedagogy transformed

> The task of educators is surely to call attention to the world, and thereby to attention itself. In essence attention involves looking at – or better, being with – the other, whether that other is the object of educational inquiry, or the student herself […] in the context of pedagogy, the other is the world that calls to be known by the student.[102]

Lewin's quote summarises the two main ambitions of the proposed methodology and describes where the structure of the CLO list gains its relevance from. The first ambition is to ensure that educators open up education to the otherness that is circularity while limiting their role to simply attracting attention to it. The second, a direct implication of the first, is to allow students to determine themselves their object of inquiry and, more importantly, who they choose to be in this otherness.

Drawing attention to otherness calls for establishing ubiquitous encounters with circularity in different learning environments, in both formal and informal settings: from small plug-in modules to be integrated into existing courses of the official study program in on-campus or blended formats, to autonomous online learning spaces, to cross-disciplinary spaces of collaboration between departments or even faculties, to the systematic exchange with industry and practice or even to highly intensive one-time events. Besides providing for these encounters, however, the role of academia becomes that of reaching out to a broader audience. The encounters should not only target students; instead, they should aim at building a community of learners, including professionals and other interested parties, as well as the teachers themselves. And in whatever form these encounters manifest, academia should allow for the more experimental academic or practice research to be brought into a curriculum despite its 'not-yetness.'[103] Or, as Ranulph Glanville frames it, to position creativity as 'looking outwards into this enormous network of everything that isn't me, treating it as a resource.'[104]

This first ambition is addressed at curriculum level by the CLO list modularity. It allows educators to choose which of the objectives fit into their curriculum and the level at which they wish to engage their students with the content. Flexibility of modular design also facilitates translating objectives into learning materials and resources.

The second ambition, minimising the role of educators while increasing that of learners, calls for establishing a new pedagogy. As explained earlier, one step towards the new pedagogy is to situate learning in the connections a learner forms by encountering a wider community of learners. This pedagogy acknowledges the learning that occurs from the exchange between individuals and their peers and with the rest of the world. But it needs to be capable of decentralising learning processes and redistributing power in learning. It needs to be a learner-centric pedagogy, thus a pedagogy that does not aim at providing definitive answers but rather enables individuals to look for knowledge relevant to their cause, allowing them the freedom to choose and focus on what is relevant to them.

Two of the existing education models come closest to the one described here; these are the research-based and the practice-based models that have gradually infiltrated architectural education in recent years. The first model, research-based, alludes to curricula designed around 'inquiry-based activities, rather than on the acquisition of subject content' and where 'the division of roles between teacher and student is minimised.'[105] This is also a model that fosters research through design, thus feeding on learners' individual fascinations and diverse cultural backgrounds. The second model, practice-based, relates mostly to the pedagogy of making and thus to a hands-on community, design-build projects. The value of this pedagogy and its relevance here lies in promoting design as a non-individualistic, non-competitive activity that promotes co-creation and learning by working together with others and setting priorities in complex, multi-actor decision-making processes.[106]

The notion that learning is not simply acquiring content but also growing and developing is inherent to connectivism as well.[107] All principles of openness, interaction, autonomy and diversity that connectivism advocates for need to be considered for their capacity to decentralise learning and placing importance on creating connective relations with others.[108] Although connectivism does not relate to a specific teaching method, it promotes the notion of networked learning not only for online formats but also for on-campus settings. Nevertheless, architectural education has always been prompted to engage in digital technologies for learning, and online collaborative formats have been around ever since the advent of the internet. Although most have been limited to reproducing traditional class exchange in online environments, in some cases like the Design Studio 2.0,[109] the Social Networked VDS,[110] and the Cooperative Studio,[111] the integration of digital technologies has facilitated a new type of learning that relies on peer collaboration and adopts research practices as a key strategy to making meaning.

This second ambition is covered by the last column of the CLO list, the competencies/attitude list: learners are continuously contested to position themselves in regard to circularity; identify what they think the interdependencies of either scales, aspects or actors are and to recognise their intricate connections. Most importantly, they are challenged to either recognise the impact of circularity or to make decisions based on their understanding of what the impact may be.

DISCUSSION

> I am I plus my surroundings, and if I do not preserve the latter, I do not preserve myself.[112]

> Education as the practice of freedom -as opposed to education as the practice of domination- denies that man is abstract, isolated, independent, and unattached to the world; it also denies that the world exists as a reality apart from people. Authentic reflection considers neither abstract man nor the world without people, but people in their relations with the world. In these relations consciousness and world are simultaneous: consciousness neither precedes the world nor follow it.[113]

The Faculty of Architecture and the Built Environment has powerfully responded to creating encounters and bringing together a greater community interested in circularity. Apart from a large number of courses related to circularity already embedded in the faculty's curricula, smaller plug-in modules are beginning to proliferate for several additional content-related courses. The faculty has also greatly invested in autonomous learning by creating a series of MOOCs and ProfEd modules. Furthermore, the CBE Hub,[114] counting more than sixty members, is the live manifestation of interdepartmental collaboration at the faculty level, while a new project is underway that will engage other faculties in cross-domain research. Industry and practice partners have often been directly involved in joint research programmes with the Hub to create new learning materials for their members or employees,[115] while a new format for intensive exchange, the Summer School, is to be launched this year. One major challenge that lies ahead, however, is finding ways of integrating the knowledge generated in these formal or informal formats into educational curricula and making sure the CLO list remains responsive to change.

Coming up with the proper pedagogy for circularity is a challenge that will continue to require attention in the future: both for finding new models of delivery and exchange that can engulf the qualities needed for learning in a complex and uncertain world, but also for finding ways of evaluating learners' experiences and allowing for their feedback to inform these models. In a world in which we don't have exhaustive answers, pedagogy should turn to support students to ask the relevant questions while remembering to listen to their answers.

Circularity is an emergent phenomenon in the network metaphor of a complex world. Some claim it has been there since before the Industrial Revolution and the advent of the Anthropocene and is only re-emerging.[116] Be that how it may, today, circularity is growing and evolving in ways that cannot be predicted, just like its re-emergence as an organising principle for reality could not have been predicted. However, the ideas that circularity operated at scale brings forward can have a significant impact on value chains, industries, and other networks.[117] Among the many reasons why circularity is relevant - and perhaps the most critical - for architectural education lies in its capacity to establish new ethics. And this is why understanding its possibilities and limitations is a task that needs to be pursued at least until consciousness is retuned to the world.

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93 Michael Batty and Paul M. Torrens, "Modelling Complexity: The Limits to Prediction," Cybergeo, December 4, 2001, accessed March 12, 2022, https://doi.org/10.4000/cybergeo.1035. Following their definition, "models are a simplification of some reality which involves distilling the essence of that reality to some lesser representation," and while for traditional, descriptive models all relations are explicit, complex systems models have chains of relations that are remain implicit, hence not testable without a radical change in perspective.

94 "The Scales to Aspects model," Circular Built Environment Hub, accessed March 12, 2022, https://www.tudelft.nl/bk/onderzoek/onderzoeksthemas/circular-built-environment

95 Olga Ioannou, Bob Geldermans, Tillmann Klein, Thaleia Konstantinou, Mariette Overschie & Alexander Wandl, "Integrating Circularity in Education: The CBE Hub Approach at the Faculty of Architecture & the Built Environment, Delft University of Technology," TU Delft: BK Books, 2022 (forthcoming).

96 Mark Mason, "Complexity Theory in Education Governance: Initiating and Sustaining Systemic Change," in *Understanding Complexity: The Future of Education Governance*, (Oslo: February 10, 2014), accessed March 12, 2022, https://www.oecd.org/education/ceri/02_Complexity%20Theory%20in%20Education%20Governance%20-%20OECD-Norway%20-%20Mason.pdf

97 The comment pertains to the constant re-evaluation and development of the "Scales to Aspects" model: in its original form, adopted in 2017, it included four scales. In its latest version, launched in autumn 2021, two additional scales were added: that of neighbourhoods and that of regions.

98 Julian Kirchherr and Laura Piscicelli, "Towards an Education for the Circular Economy (ECE): Five Teaching Principles and a Case Study," 3.

99 Basarab Nicolescu, "Methodology of Transdisciplinarity - Levels of Reality, Logic of the Included Middle and Complexity," 20.

100 Neri Oxman, "Age of Entanglement," *Journal of Design and Science*, January 13, 2016. https://doi.org/10.21428/7e0583ad.

101 Andrew Jamison, Steen Hyldgaard Christensen, and Lars Botin, *A Hybrid Imagination: Science and Technology in Cultural Perspective* (San Rafael, California: Morgan & Claypool Publishers, 2011), 4.

102 David Lewin, "Behold: Silence and Attnetion in Education," *Journal of Philosophy of Education* 48, no. 3 (2014), https://doi.org/10.1111/1467-9752.12074.

103 Amy Collier, and Jen Ross, "For Whom, and for What? Not-Yetness and Thinking beyond Open Content." *Open Praxis* 9, no. 1 (March 31, 2017): 7. https://doi.org/10.5944/openpraxis.9.1.406.

104 Veronika Valk, "Powering up - Interview with Ranulph Glanville," in *The ADAPT-r Creativity Book*, ed. Johan Verbeke (Brussels: KU Leuven, 2017), 235.

105 Ron Griffiths, "Knowledge Production and the Research–Teaching Nexus: The Case of the Built Environment Disciplines," *Studies in Higher Education* 29, no. 6 (December 2004), 722, https://doi.org/10.1080/0307507042000287212 Griffiths examines research-teaching nexus specifically for the built environment disciplines and comes up with four models; research-led; research-oriented; research-based; research informed.

106 Ashraf M. A. Salama, *Spatial Design Education: New Directions for Pedagogy in Architecture and Beyond* (Farnham Surrey, England; Burlington: Ashgate, 2015), 125, 127, 230-233. Salama describes three pedagogical models that developed around the practice-led idea: community-based; design-build and live-projects.

107 Stephen Downes, *Toward Personal Learning: Reclaiming a role for humanity in a world of commercialism and automation* (National Research Council Canada (CC BY-NC-SA), 2017): 6.

108 Ibid: 336.

109 Burak Pak, and Johan Verbeke, "Redesigning the Urban Design Studio: Two Learning Experiments," *Journal of Learning Design* 6, no. 3 (December 12, 2013): 45–62, https://doi.org/10.5204/jld.v6i3.160

110 Jeremy J. Ham, and Marc Aurel Schnabel, "Web 2.0 Virtual Design Studio: Social Networking as Facilitator of Design Education," *Architectural Science Review* 54, no. 2 (January 1, 2011): 108–16, https://doi.org/10.1080/00038628.2011.582369.

111 Olga Ioannou, "Architectural education on the internet and the constitution of the learning subject within the extended communities of knowledge," (Ph.D., National Technical University of Athens, 2019), http://hdl.handle.net/10442/hedi/45497.

112 Jose Ortega y Gasset, *Meditations on Quixote* (New York: The Norton Library, 1963).

113 Paulo Freire, *Pedagogy of the Oppressed*, trans. Myra Bergman Ramo (New York; London: Continuum, 2005), 81.

114 CBE Hub was established in 2017 with the aim of to promote the development and exchange of knowledge towards a circular built environment. For more info please visit: https://www.tudelft.nl/bk/onderzoek/onderzoeksthemas/circular-built-environment.

115 With refenrence to Remanpath, Cared, and FacadeReLog.

116 Birgit Hopff, Steffen Nijhuis, and Leendert A. Verhoef, "New Dimensions for Circularity on Campus-Framework for the Application of Circular Principles in Campus Development," *Sustainability* 11, no. 3 (January 24, 2019), 627, https://doi.org/10.3390/su11030627.

117 Fenna Blomsma and Geraldine Brennan, "The Emergence of Circular Economy: A New Framing Around Prolonging Resource Productivity," *Journal of Industrial Ecology* 21, no. 3, (2017): 603.

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PLANIRANJE PROMENA: METODOLOŠKI OKVIR ZA INTEGRACIJU CIRKULARNOSTI U NASTAVNE PLANOVE I PROGRAME ARHITEKTONSKOG FAKULTETA I GRAĐENE SREDINE, TU DELFT

Olga Ioannou, Bob Geldermans, Tillmann Klein, Alexander Wandl

Ovaj rad postavlja metodološki okvir za integraciju cirkularnosti u arhitektonske nastavne planove i programe, predstavljajući blokove koji su doveli do njegove konceptualizacije. Prvi blok (Deo A) ispituje kako je složenost uticala na učenje i, , posebno, na arhitektonsko obrazovanje. U radu se polazi od ideje da znanje proizvodi dalju nesigurnost u uslovima kritične složenosti. Štaviše, najviši nivoi složenosti zahtevaju najmanje naučnih pristupa. Zatim, ispituje glavne izazove koji proizlaze iz ove promene: jedan je da se učenje identifikuje sa sposobnošću pojedinaca da donose utemeljene odluke i konceptualizuje kao znanje koje se može primeniti. Drugo, obrazovanje treba da se opredeli za pedagogiju koja može da podrži učenje kroz donošenje odluka. Arhitektonsko obrazovanje bi, posebno, trebalo da bude u stanju da neguje novu vrstu profesionalizma, gde pojedinci preuzimaju odgovornost za svoje projektantske odluke koje se protežu izvan estetskog područja. Ali šta može da podstakne nastavne planove i programe da postanu osetljiviji na trenutnu ekološku, društvenu i političku realnost? Drugi blok (deo B) istražuje cirkularnost. On ispituje njegovu relevantnost za arhitektonsko obrazovanje zbog mogućnosti da funkcioniše i kao operativna šema i kao sistem vrednosti. Štaviše, budući da je koncept u nastajanju, cirukularnost može imati koristi od akademskog istraživanja, ali takođe može podržati pedagogiju koja se fokusira na pomaganje učenicima da nauče kako da uče. Predloženi metodološki okvir (Deo C) se zasniva na ova dva bloka i na fakultetskom istraživanju o cirkularnosti kako bi se razvila šema koja ukazuje na relevantne sadržaje za nastavu cirkularnosti, kako se mogu formulisati ciljevi za njegovo integrisanje u nastavne planove i programe i koja vrsta pedagogije je pogodna za podršku integraciji.

KLJUČNE REČI: ARHITEKTONSKO OBRAZOVANJE; CIRKULARNA GRAĐENA SREDINA; SLOŽENOST; TRANSFORMATIVNA PEDAGOGIJA