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Sustainable and Resilient Infrastructure

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tsri20

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To cite this article: Vineetha Nalla, Cassidy Johnson, Nihal Ranjit, Gargi Sen, Ananya Peddibhotla, Mona Chhabra Anand, Neha Bhatia & Amir Bashir Bazaz (2022): Considering curriculum, content, and delivery for adaptive pathways: higher education and disaster resilient infrastructure in the Indian urban context, Sustainable and Resilient Infrastructure, DOI: 10.1080/23789689.2022.2134645

To link to this article: https://doi.org/10.1080/23789689.2022.2134645

Published online: 20 Oct 2022.

SUSTAINABLE AND RESILIENT INFRASTRUCTURE
https://doi.org/10.1080/23789689.2022.2134645

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Considering curriculum, content, and delivery for adaptive pathways: higher education and disaster resilient infrastructure in the Indian urban context

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ABSTRACT

In the context of urbanisation in the Global South and increasing climate-induced disaster events, fostering resilience in infrastructure systems is critical to delivering on goals of economic development, poverty reduction, and climate action. Adaptive pathways, given its inherent consideration of uncertainty and an embedded feedback mechanism, becomes a necessary conceptual underpinning to deliver on the resilient infrastructure challenge. We argue that knowledge and iterative learning are key components that enable the flexibility of adaptive pathways. Higher education (HE) plays a critical role in influencing knowledge that is adaptive and dynamic to respond to this challenge. This study adopts a qualitative approach with a case study design to identify gaps in how urban resilient infrastructure is conceptualised and taught in HE institutions. . The study finds that interdisciplinarity, when reflected in the elements of content, pedagogy, and delivery would foster substantial critical thinking and reflexivity required to address the resilient infrastructure challenge.

ARTICLE HISTORY
Received 26 August 2022
Accepted 6 October 2022

KEYWORDS
Disaster resilience; infrastructure; adaptive pathways; higher education; urban; interdisciplinary

1. Introduction

Urbanisation in the Global South is one of the most dominant phenomena of the 21st century, with the promise of pulling millions out of poverty and creating sustained livelihood opportunities. Complex and interconnected infrastructure systems in urban areas are critical to delivering on this promise. However, the rapid pace of urbanisation and the changing nature of climate continue to pose challenges in terms of exposure and vulnerability, as infrastructure and basic services attempt to keep pace with the growth (Gunter & Massey, 2017). In addition, weak and fragmented governance, and poor implementation of standards, significantly impact infrastructure systems, thereby disrupting economic activities. These in turn have implications for the goals of poverty and inequality reduction.

According to the World Bank (2019), the annual cost of infrastructure disruptions due to disasters and climate risks ranges from USD 391 billion to USD 647 billion in low- and middle-income countries. India alone, the Global Climate Risk Index 2020 estimates, suffered infrastructural loss and damage of USD 37 billion in 2018 due to extreme climate events (Germanwatch, 2019). Given that large-scale infrastructure projects are fast becoming the pivotal strategy for economic development (Sharma, 2021), the value of the infrastructure that stands to be damaged is increasing (UNDRR, 2019) and its impacts are far-reaching. Importantly, existing infrastructure that is locked in as an outcome of past decisions and actions has often perpetuated and exacerbated risk due to constraints on the system's ability to adapt. Decisions made today will lock in vulnerability if they fail to consider these impacts (Roy, 2019). Amidst robust projections of an increase in the frequency and severity of climate-induced disaster events, it becomes imperative to create infrastructure systems that can protect and service new and existing urban populations and retrofit existing infrastructure systems to make them resilient. While doing so, care must be taken to ensure that these infrastructure systems deliver on the goals of poverty reduction, disaster resilience, climate action, sustainable urbanisation, and sustained economic and human development and does so in a resource-constrained world with competing priorities.

The complex, interconnected, and uncertain nature of the resilient infrastructure challenge calls for planning approaches that are dynamic and responsive to changing conditions. Adaptive pathways, particularly

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in the climate change discourse, have been proposed as an approach to incorporate flexibility into decision-making processes while also accounting for future uncertainties (Berkes, 2007; OECD, 2018). Werners et al. (2021) conceptualise adaptive pathways as 'sequences of actions that can be implemented progressively, depending on how the future unfolds, and on the development of knowledge and stakeholder preferences' (p. 266). Adaptive pathways, given its inherent consideration of uncertainty and an embedded feedback mechanism, therefore becomes a necessary conceptual underpinning to deliver on the resilient infrastructure challenge.

Recent literature has illustrated the potential of education to increase social-ecological systems' flexibility and resilience, and this has been the subject of an expanding amount of theoretical and empirical studies (e.g., Fazey et al., 2007; Krasny et al., 2009; Spellman, 2015; Tidball & Krasny, 2010, 2011). Specifically, education plays a critical role in fostering knowledge of urban areas and of climate change, as well as enabling innovative learning that places emphasis on the capacity to identify the root causes of issues and create new responses (Tong et al., 2019). In fact, Feinstein and Mach (2020) argue that the 'unique and transformative contribution of education lies in adaptation learning support: curricular, pedagogical, and technological resources that prepare people for complex adaptive decision-making and help them solidify learning during that work' (p. 317).

Given this, we argue that knowledge and iterative learning is a critical dimension that enables flexibility and 'dynamism' of adaptive pathways. Knowledge exchange and learning take place across formal and informal contexts including schools, higher education institutions (HEIs), homes, communities, civil society organisations, and social movements (Tikly et al., 2020). In this paper, we concern ourselves with one specific aspect of the knowledge and learning system, which is higher education (HE).

HE plays a critical role in preparing a new generation of urban practitioners and policymakers by influencing knowledge, skills, and attitudes to deliver on the resilient infrastructure challenge. However, in India, the HE systems, as they are currently configured, often fail to achieve this. Significant lock-ins to disciplinary orientation in HE and limited exposure to the field and on-ground practice undermines a robust feedback mechanism – one that allows for learning and iterative intervention that is happening on the ground to make its way back to the classroom – which ensures that the curriculum is relevant to contemporary realities. Thus, the aim of this research is to consider how HE in India can be reimagined to be adaptive and dynamic to respond to the resilient infrastructure challenge. By taking the case of HEIs in India, this research explores (i) how is urban infrastructure resilience taught in HEIs in terms of curriculum, content, and pedagogy? And, (ii) what are the barriers to equipping learners with adequate knowledge of urban infrastructure resilience?

The paper is structured as follows: In the next section, relying on existing literature, we outline linkages between the urban, resilient infrastructure, and education. Following this, we explore the current status of HE in India which focuses on disaster resilient infrastructure (DRI). The section later provides an overview of the various materials and methods that we followed for carrying out this research. Next, we describe the findings of this study along with two aforementioned broad but interrelated questions. Finally, we discuss the principles and rubric of a reimagined curriculum that fosters dynamism and flexibility to deliver on the resilient infrastructure challenge.

2. Literature review

2.1. Urban, Disaster Resilient Infrastructure (DRI) and education

The central role of urban areas in propelling a more equitable and sustainable future is increasingly being accepted. However, globally, urban areas are struggling to strike a balance between overlapping and often conflicting social, economic, and ecological mandates. Sustainable development outcomes in urban areas are complex and are a combination of a wide range of different processes (Krellenberg & Koch, 2021, p. 201). The United Nations (UN) Sustainable Development Goals (SDGs), particularly SDG 11 reflects this. Urban areas, particularly in the Global South, are complex, multi-hazard environments with large sections of the population living in poverty and vulnerable to both everyday risks and to risks arising from extreme events (Bazaz & Parnell, 2021). To that end, SDG 11 has strong positive correlations with SDG 3 (Good health and well-being), SDG 4 (Quality Education), SDG 5 (Gender Equality), SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Works and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure; Fonseca et al., 2020, p. 12) and SDG 13 (Climate Action; Krellenberg & Koch, 2021, p. 201);

necessitating a cross-sectoral, and implicitly an interdisciplinary approach to creating sustainable and resilient cities (Pelzer & Geertman, 2014, p. 1).

These development goals rely on an intricate scaffolding of infrastructure systems which inevitably play a role in the reduction and exacerbation of vulnerabilities and risks in cities (Tellman et al., 2018). Against the backdrop of climate change and ensuing challenges, the multi-actor ecosystem of critical infrastructure systems in the cities needs to be optimally flexible and adaptable to changing conditions. Thus, adaptive pathways toward resilient infrastructure systems need to consider and incorporate adequate flexibility to account for future uncertainties (Butler et al., 2015; Werners et al., 2021). However, urban actors struggle to keep pace with the challenges in developing resilient systems and consequently in developing resilience governance strategies that encapsulate its diverse factors (Therrien et al., 2021). The challenges in the perception and response of actors draw upon their capacities, and here, education is a critical component of building the necessary skills and capacities to facilitate adaptation to climate change in the dynamic and uncertain context of growth and impacts (Reimers, 2021, p. 4).

Education's potential to increase social-ecological systems' flexibility and resilience has been widely researched in theoretical and empirical studies (e.g., Fazey et al., 2007; Krasny et al., 2009; Tidball & Krasny, 2010, 2011). Notably, Tong et al. (2019) in their study have illustrated the role of urban climate education in building resilience by taking the case of Da Nang City in Vietnam. They borrow the Climate Resilience Framework (CRF), which was first developed by Tyler and Moench (2012), and seek to define the key elements of a resilient urban system comprising systems (urban infrastructure/ecosystems), agents, and institutions. In the CRF model, education serves as the basic ground for learning and sharing knowledge on climate change adaptation among multiple stakeholders toward building capacity for urban resilience.

Specifically, formal education plays an avant-garde role in fostering knowledge on urban and climate change, from primary to secondary level. Importantly, as elucidated by Longstaff et al. (2010), innovative learning that places emphasis on the capacity to identify and design new responses is essential in education (Tong et al., 2019). As Eriksen et al. (2015) argue, decision-makers choose what environmental threat to respond to, when it matters and for whom, and how to respond. Education, especially HE, when appropriately conceived and drawn from an interdisciplinary perspective can not only increase the environmental awareness of climate change and its impacts but also enable effective adaptation to climate change mitigation (Feinstein & Mach, 2020; UNICEF, 2019). It can also foster adaptation learning support in terms of curriculum, pedagogy and resources that prepares future practitioners for adaptive decision-making (Feinstein & Mach, 2020).

In this context, HE has a critical role to play in improving the capacities of practitioners, decision-makers, and communities, therefore serving as a foundation for adaptive pathways. However, conventional HE curricula are seldom oriented to developing knowledge, skills, and capacities necessary for interconnected thinking (Bazaz & Parnell, 2021; Little, 1999) which the complex nature of urban resilient infrastructure requires. Disciplinary silos and insufficient knowledge flow from practice to classroom and back cumulatively undermine the building of effective capacities to deal with this challenge.

Given this, Filho et al. (2020) argue for the need to reimagine HE in terms of its 'content, pedagogy, and contextual, institutional and sector-wide constraints' (p. 2) in order to develop critical thinking together with reflexive and transformative educational methods that can reposition knowledge and learning practices to lead to change (Anand et al., 2021). These would enable a transition from conventional siloed disciplinary-based approaches in content and pedagogy to enabling deeper enquiries that draw on the physical, social, political, and environmental aspects. Apart from the requirement of adequately capacitated faculty to deliver on these goals, cross-institutional partnerships to enable knowledge and innovative experiments in curricula and pedagogy could be a way forward. Considering this, there is a need to assess HE through the lens of deficits in knowledge, methods and capacities to propose necessary curricula improvements.

2.2. Status of DRI across major disciplines in HE: Using climate change education as a proxy

Climate change is one of the most dominant contemporary challenges that we are grappling with. There have been considerable advancements in the science, policy, and practice on questions of climate change in the past few decades. Given this understanding, in this section, we review the status of themes related to DRI across major disciplines in HE. Here, recognising that DRI is a relatively new concept, we expanded our search to first understand the uptake of climate change in HE which would lay a foundation to gauge the uptake of DRI.

HEIs across the world are trying to complement the decarbonisation and climate change mitigation goals of national governments or private conglomerates, by integrating climate change as a part of their curriculum

(Filho et al., 2021). Research (Hamin & Marcucci, 2013; Hess & Collins, 2018; Hurlimann, 2009; Leichenko & O'Brien, 2020; Majid et al., 2011; Preston-Jones, 2020; Roy et al., 2017; Siperstein et al., 2017) into existing HEI curriculums across different disciplines have investigated the mainstreaming of concepts and impacts of climate change, and other allied subjects. Among these, far more have explored the integration of climate change into urban planning than other disciplines such as engineering studies, management, business studies, and humanities. Furthermore, most of these studies are located in the developed world compared to the developing world of the Global South. The UN-Habitat (2009) notes that while globally, only one-third of planning schools teach climate change, it is important to note that most of these planning schools are located in developed countries, while their counterparts from the developing world are still lagging behind (Majid et al., 2011). However, given that climate change and climate change-induced disasters are some of the most significant challenges facing society today, it is being recognised as a critical issue of relevance across both science and politics (Filho, 2010). Disasters (particularly those in the urban) unfold on different geographic and temporal scales and occur at the intersection of natural and built environments and social and technical systems. Consequently, hazards and disaster research has long engaged researchers across various disciplines in attempting to bridge the academic, theory, policy, and practice divide (Peek & Guikema, 2021). Indeed, tackling these issues demands interdisciplinary approaches – but universities have struggled to ensure disciplines work cooperatively to develop an interdisciplinary understanding of the problem at hand (Davison et al., 2014).

Studies have identified urban planning as a profession which could make a positive contribution to achieving SDGs – although concerns have been raised as to whether HEIs are sufficiently integrating climate change knowledge thereby preparing them to respond to the challenges of climate change (Hurlimann, 2009; Preston-Jones, 2020). From the developed countries, studies with respect to planning curricula reveal that while climate change and allied subjects are being taught to some extent, their integration has not been uniform. For instance, in the United Kingdom, Preston-Jones (2020) found that 40% of the courses reviewed did not contain any climate change-related content as part of the core curriculum. The theme is mostly featured in electives. On the other hand, she did find that some modules covered climate change without explicitly stating it in the module title or description. In the United States (US), Hamin and Marcucci (2013) found that while basic concepts of climate change such as climate equity, adaptation and mitigation were already beginning to appear in US planning schools, ideas of vulnerability, risk and resilience were found only in isolated seminars and not yet mainstreamed into the core curriculum. In Australia and New Zealand, Gunder (2006) reports that the uptake of climate issues and environmental sustainability has been limited.

In the developing world, the uptake has been further lagging. In Malaysia, for instance, Majid et al. (2011) note that a 'proper education in terms of equipping students with the required wisdom in tackling climate change, encompassing sustainability thinking, skills, ideas and best practices for a climate change sensitive planning' (p. 954) is still missing from the curriculum. Their findings indicated that similar to several developing countries, curricula are designed to prepare graduates to respond to rapid urbanisation demands and, therefore, emphasise 'physical design aspects and policy formulation which focus more on methods of planning analysis and physical plan drawing. In fact, the emphasis is still on human comfort rather than sustainability' (p. 954). In India, Roy et al. (2017) study of three different planning schools revealed an average coverage of disaster risk reduction and climate change adaptation tools, techniques, and approaches to equip future practitioners. However, they do note that while there have been efforts in introducing the subjects, it 'has not resulted in a systematic integration of this area within the school's educational and research activities' (p. 19). In essence, across the world, while there has been an uptake of these themes to varying degrees, integration into core curricula has been absent.

A major setback, Hurlimann (2009) explains, is due to the lack of integrating insights from planning practice in the curricula, as consultations with planning professionals on framing the curriculum are limited or absent. Others concur stating 'a close interaction between education and practice is essential to assure that students are gaining the most relevant and up-to-date knowledge and that practice has the benefit of the breadth and depth of view that research and pedagogy can provide' (Hamin & Marcucci, 2013, p. 484) and that 'it would be difficult to speculate on the future of planning education without thinking of future of planning practice' (Roy et al., 2017, p. 3). Another major impediment highlighted across these studies was the lack of adequately qualified and capacitated staff to consolidate findings and mainstream them into curricula. Importantly, since climate change is an issue that demands an interdisciplinary understanding and collaboration across disciplines to conceptualise solutions, there is a dearth of faculty who can teach from an interdisciplinary perspective. Disciplinary lock-ins in universities, Davison

et al. (2014) explain 'is reinforced by hierarchical, top-down modes of leadership, individualised and competitive pathways of career progression, and administrative and financial structures premised on competition between sub-organisational units' (p. 98). This means that interdisciplinary teaching is often 'restricted to small organisational units offering niche programs for a minority of students rather than being embedded across the curriculum and available to all students through collaboration between disciplines' (p. 98–99). Therefore, there is a need for HEI to develop broader knowledge among student learners about climate change understood from the perspective of natural sciences, social sciences, humanities, architecture, planning, etc., towards both understanding of climate change and the complexity of developing solutions to address it (Filho, 2010).

Furthermore, a world survey of climate change education across HEIs by Filho (2010) suggests the prevalence of these themes in natural and social sciences, and less so in engineering and other disciplines. The study argues that 'there seems to be room for improvement in respect of the emphasis given to the human dimensions of climate change' (Filho, 2010, p. 11), and in fact, with respect to the emphasis on climate change in HEI, this study indicates that 'the frequency of occasions where the topic is either not well covered and poorly covered is rather high' (p. 17). Siperstein et al. (2017) note that research and curricula in humanities have also lagged behind natural and social sciences. Humanities play an important role, especially in communicating the science and policymaking around climate change and disasters. More so, in the exploration of responses to address this issue where the proposal of solutions requires students to recognise the social dimensions of climate change and identify entry points for sustainability transformations (Leichenko & O'Brien, 2020). Siperstein et al. (2017) concur that the 'diverse spatial and temporal scales of this "wicked problem" demand more of the humanities than the mere translation of climate science for lay readers' (p. 3). Although a need has been identified for humanities to integrate these themes into its curricula and for curricula on climate change to integrate humanities into their teaching, 'far more scholarship has attended to teaching climate change in science and policy disciplines' (Siperstein et al., 2017, p. 3). While these studies do shed light on the integration of climate change and allied subjects, the integration of disaster resilience and DRI is absent.

In light of this, the current study aims to explore how these themes are being taught in Indian HEIs and the gaps therein, and how HE in India can be reimagined to be adaptive and dynamic to respond to the resilient infrastructure challenge.

3. Methods

The study adopts a qualitative approach with a case study design to identify the gaps in the current manner in which urban resilience and DRI is conceptualised and taught in HEIs in India. The study was undertaken in three phases (i) Exploratory phase – during which we developed a database of HEIs and programmes that teach topics relevant to urban resilience and DRI, (ii) Documentation Phase – where we developed a set of case studies supported by primary in-depth interviews with faculties and academics across select HEIs and disciplines, and, (iii) Explanatory Phase – where we analysed the findings from the review of the programme curricula and interactions with faculty members to understand the

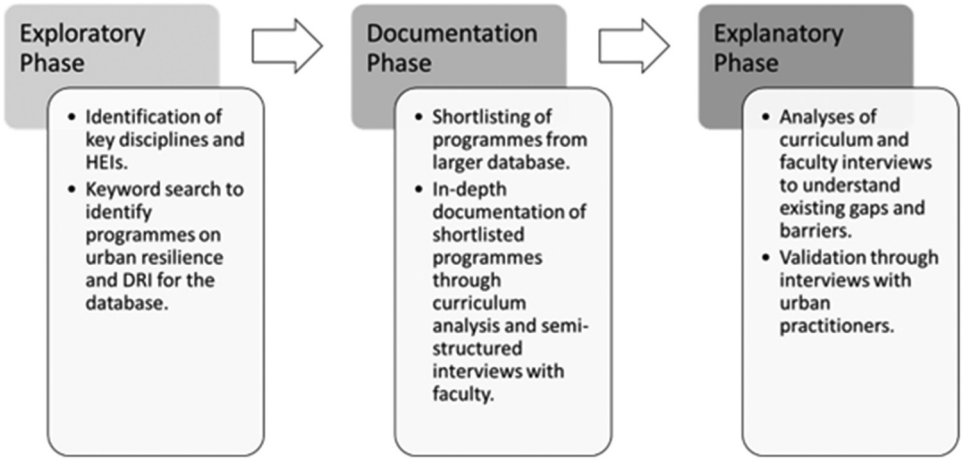

Figure 1. Phase-wise summary of methods and data collection.

existing gaps and barriers in knowledge, capacities, and skills. Figure 1 elucidates the key actions in each phase, the rationale behind the same and the outputs thereby.

3.1. Phase 1: exploratory

This phase focused on the identification and creation of a database of HEIs and programmes that taught topics related to urban resilience, DRI, and more broadly disaster risk reduction (DRR) and disaster management (DM). This database was created in two stages – first, from the multitude of disciplines taught in HEIs in India, we narrowed our search to disciplines of Engineering, Planning, Architecture, Management, and Social Sciences. This scoping is based on our protracted engagement in the disaster space and more broadly with the urban which has shown us that practitioners and researchers from these disciplines are at the forefront and are more likely to closely engage with questions pertaining to the urban and more specifically on resilience and infrastructure systems.

Second, we utilised the method employed by Hamin and Marcucci (2013), and Hess and Collins (2018), a keyword search, to identify degree programmes that taught topics on urban resilience and DRI as part of their curriculum within the shortlisted HEIs. Since urban resilience and DRI are niche topics, in addition to using these keywords, a search was conducted using the keywords: 'disaster risk', 'disaster studies', 'infrastructure resilience', 'climate change', and 'sustainability'. Only programmes containing these keywords in their curriculum were included in our database. In total, the database consisted of 14 HEIs and captured details such as the name of the HEI, discipline, whether the HEI is public or privately funded, the name of the degree programme, department or centre offering the programme, the degree level (certificate course, diploma, undergraduate, postgraduate, doctoral), programme duration, and identifying based on the keyword search, and pedagogical methods, whether the themes were included as a part of the core or elective courses in these programmes. Lastly, the database categorised the courses based on three broad categories: specialised programmes, core and electives courses.[1] While our primary focus was on specialised programmes and core courses, elective courses were included to capture all courses on urban resilience, DRI and DRR courses that were on offer.

3.2. Phase 2: documentation

In this phase, a set of 12 programmes were selected from a shortlist of eight HEIs for in-depth investigation and documentation from the larger database. From each discipline, we selected two programmes, one each from a public-funded HEI and a private-funded HEI, that were closely aligned to themes of urban infrastructure resilience. For each discipline, the choice of programmes has tried to include at least one which is conventional in its learning objectives with respect to the discipline and the other that is designed to be more inter-disciplinary and may be more attuned to the concepts of urban resilience or infrastructure resilience. Publicly available curricula and contents were analysed to ascertain whether the programmes had a substantial focus on urban resilience and DRI, what was being taught, and the pedagogical approaches employed. In addition to this, interviews were conducted with 12 faculty members across these programmes. Faculty members we interviewed comprised senior faculty, programme heads, departmental heads or deans who play a pivotal role in the designing and delivery of these programmes. This was particularly useful in cases where programmes did not have a detailed description of their curriculum. The interviews were conducted online over video conference applications and ranged between 40 and 60 minutes each. Interactions with faculty helped us gain a deeper understanding of the pedagogical approaches and tools utilised by them (which were not publicly available) and shed light on the overarching framing of the courses. Further, interviews with faculty provided insights into the larger position of the HEI with respect to these themes. We observed that the broader goals/vision of the institution or the departmental/school agenda often drives the way curricula are designed and taught. Roy et al. (2017) explain that oftentimes, faculty face challenges in incorporating these themes into the curriculum due to a lack of adequate capacities and support from the department or the university.

3.3. Phase 3: explanatory

In this phase, four of the authors independently analysed the findings from the review of course curricula and interactions with faculty members to understand the existing gaps and barriers in knowledge, capacities, and skills to deliver on the resilient infrastructure aspirations. This analysis was complemented with in-depth, semi-structured interviews with four select practitioners from India who are associated with a range of

organisations working on addressing challenges of urban resilience, resilient infrastructure and DRR (at multiple scales), and are actively involved in recruiting learners from the select disciplines. Similar to the faculty interviews, these interviews were also conducted online over video conference applications and ranged between 40 and 60 minutes each. These interactions helped us gain insights into the skills, knowledge, and capacities they look for in potential recruits and the employability of professionals graduating from HEIs to work in the sector. The interviews also enquired into their perception of what they feel is currently lacking in the programmes offered by the HEIs. The combined insights of the faculty and the practitioners enabled the assessment of the programmes from the perspective of educators as well as practitioners/employers and consequently enabled us to comprehend the responsiveness of the HEIs to the employability needs of the urban and infrastructure resilience domain.

3.4. Limitations

There are several limitations to this research, particularly in compiling the database. While the database was designed to capture publicly available information, detailed curricula were seldom publicly disclosed by HEIs. As such, only those programmes within HEIs that had adequate details of the curriculum available on their online websites were included in the database. Hess and Collins (2018) and Preston-Jones (2020) highlight a limitation of using a 'concept-driven' keyword search approach, which is pertinent to this analysis as well, wherein some modules may cover the themes of urban resilience and disaster risk or employ a disaster risk lens without explicitly stating so in the module description and hence would not be captured in this database. The sample size has been kept small to do justice to the qualitative, in-depth nature of the review.

4. Results

4.1. How is urban infrastructure resilience taught in HEIs in terms of curriculum, content, and pedagogy?

The database compiled during the *exploratory phase* comprises 252 programmes across 14 HEIs. During the compilation of the database, we found that there existed little to no courses or specialised programmes *explicitly* covering themes of urban infrastructure resilience and DRI. Closer inspection revealed different combinations of themes such as 'Disaster, Infrastructure', 'Environment, Ecology, Climate Change', 'Infrastructure Resilience, Sustainable Development' among others, which are distributed across the core and elective courses taught in these programmes. This indicated that articulation of urban infrastructure resilience is not a common theme/domain of study within the disciplines of engineering, architecture, planning, management, and social sciences. There were 18 programmes that contained no topics relevant to the domain. These were subsequently excluded from the database, and the remaining 234 programmes were considered for further perusal.

In the *documentation phase*, we studied the structure and curriculum of a selection of 12 programmes shortlisted from the larger database across the Engineering, Architecture, Planning, Social Science, and Management disciplines that were closest to themes of urban infrastructure resilience. The review of the curricula was complemented with semi-structured interviews with 12 faculty from these institutions.

An analysis of the curricula indicated that while urban infrastructure resilience was not a prominent theme in the abovementioned programmes, few of them had some courses (either core or elective) that dealt with themes of disaster resilience, urban infrastructure planning and design. We found that conventional programmes in Engineering, Architecture, and Planning are limited by the priorities of the disciplines and focus on imparting technical knowledge to the learners with the intention of developing skilled professionals who can work in the core domain of the field. In these programmes, the socio-economic aspects are undermined by the emphasis on more physical, tangible aspects of development as viewed through the lens of each discipline. For instance, a graduate with a master's degree in Civil Engineering or Water Resource Engineering would be well-trained in understanding the water distribution model of the city and would have the requisite skills to design a drainage system to address the issue of flooding in the city. While their training equips them to address the physical vulnerabilities of the city, they fall short in being responsive and sensitive to the vulnerabilities and needs of the most disadvantaged and marginalised communities in the city as the programme does not expose them to ideas of equity and differential vulnerability, nor does it focus on unpacking the complexities of the urban, where these systems would be located.

However, more recent engineering and planning programmes (three cases from our database) are breaking away from the rigidity imposed by the discipline and moving towards interdisciplinary teaching and learning, pushing students to explore and understand the 'problem' better than proposing 'solutions' to address the same. These programmes emphasise developing more

holistic perspectives and locating themselves in the context of climate-responsive and responsible development.

A specialised programme in disaster risk offered by a social science institute employs a more nuanced lens of teaching disaster risk and resilience. While the programme does not have a course that explicitly focuses on questions of urban infrastructure resilience, they do have courses that critically analyse urban spaces, the built environment, and planning. As such, the urban in itself is a significant domain of enquiry in the programme. Moreover, questions on infrastructure and resilience are not explored from a technical point of view. Rather, these principles and frameworks are critically analysed through the lenses of vulnerability, equity, and justice.

Apart from programmes in architecture and planning, very few programmes set a context for the urban as they were thought to be outside of the core disciplinary focus. Traditional management programmes seldom had courses that introduce learners to the complexities of urban areas or to themes of risk, resilience, or climate change impacts. Rather, they prioritised management subjects that they perceived would be of more consequence for securing job offers – a key indicator of success in management programmes. Nevertheless, in recent years, management schools have seen courses that explore themes pertaining to urban and sustainability. For instance, the course on 'Sustainable and Liveable Cities' offered as part of the Master's in Business Administration (MBA) programme uses informal settlements as an entry point to explore the complexities of 'the urban'. Issues pertaining to land and access to basic infrastructural services within slums are viewed through a management lens to arrive at questions of equity and access. However, such courses are few in number and often are a result of individual efforts and interests of faculty rather than an institutional intent to include these themes in the curriculum.HT

Apart from contact classes and lectures, the pedagogic methods employed in all the programmes we reviewed were consistent with their disciplinary inclinations. For instance, studios[2] were the preferred pedagogic tool to explore interdisciplinary themes in architecture and planning programmes. Similarly, specialised programmes in disaster risk had field visits to disaster-affected regions, while management programmes relied on case studies. These pedagogic methods, though not widespread, allow more opportunities to engage with on-ground realities and practitioners.

4.2. Barriers to equipping students with adequate knowledge of urban infrastructure resilience

An analysis of the curricula and interactions with faculty members and practitioners during the *exploratory phase* of the study shed light on the existing gaps and barriers in knowledge, capacities, and skills to deliver on the urban infrastructure resilience aspirations.

4.2.1. Content

Our analysis informs that the way the theme of urban infrastructure resilience is taught in HEIs lies on a spectrum between 'disaster resilience' on one end and 'infrastructure planning and design' on the other. Owing to this, barring a few programmes, the context of urban areas is not uniformly taught. A recognition of the urban and an appreciation of its complexities are pertinent to understanding urban infrastructure systems and disaster-resilient infrastructures. For instance, while technical aspects of infrastructure resilience are taught in engineering programmes, they were rarely situated within the larger context of the urban and its complexities such as urban informality and poverty. Reflecting on management programmes, a faculty noted that courses wherein the urban context is discussed are minimal and those that do, limit discussions to themes such as project management and operationalisation of infrastructure projects rather than critically examine these projects or explore the interconnectedness of urban systems

Interviews with faculty further suggested that while there is a growing recognition of the need to discuss the context of urban and the interconnectedness of urban systems, it falls short of being incorporated into the curriculum. In addition to this, themes of climate change and DRR do not feature prominently in the core curriculum, except for specialised programmes. In most disciplines, themes about DRR and climate change and more broadly on the environment feature at best as electives. Interestingly, while the themes of climate change, DRR and resilience did not feature in the curricula of planning and architecture programmes, interviews with faculty revealed that, though not explicitly mentioned, these themes are often discussed as part of the studios which are critical components of these disciplines.

4.2.2. Gaps in the operationalisation of course and mode of delivery

Across disciplines, almost all the faculty we interacted with recognised the need for interdisciplinary teaching. However, they noted that this has rarely been attempted

in most disciplines as the majority of the faculty, institutional structures, and processes, which are locked into disciplinary canons, often impede such changes in curricula. For faculty comfortable within their disciplines and with the curriculum, delivering on interdisciplinarity would require reviewing content from disciplines that they are less familiar with, which could be thought to be cumbersome given existing teaching and administrative commitments. Nevertheless, our interactions indicated that certain institutions and a handful of faculty members (predominantly early to mid-career faculty) are gradually becoming more receptive to the idea of interdisciplinary teaching and learning, wherein the emphasis is on developing a nuanced understanding of the problem before leapfrogging into the 'solution' space. We observed that several such courses were being offered as elective courses by independent research centres within the HEIs.

In essence, in core disciplinary education (particularly Engineering and Management), the emphasis is on equipping learners with technical skills that align with their disciplines as the programmes are designed to cater to the market demand. However, in our interviews, some faculty have highlighted that these programmes overlook engaging learners with on-ground realities and real-world problems. This disconnect can be partly explained by the lack of a strong practice or place-based learning component in these programmes, thereby leading to a myopic view of the urban resilient infrastructure challenge. Practitioners we interviewed, who belong to organisations working across global networks of local and regional governments to drive the equitable and sustainable development of cities, also alluded to this. They noted that graduates from engineering and planning programmes who work in the domain of urban infrastructure tend to focus on proposing technical solutions to 'fix' the urban infrastructure challenges before developing a nuanced understanding of the problem.

5. Discussion – Reimagining higher education to mainstream principles of adaptive pathways and facilitate delivery of resilient infrastructure

Resilient infrastructure systems are crucial to minimise disaster impacts, limit maladaptation and ensure uninterrupted service delivery. All of the above dimensions are critical to ensure sustained efforts towards goals of poverty reduction and sustainable economic and human development. In the urban context, owing to the complex and interconnected nature of infrastructure, the challenge is immense and calls for institutionalising a dynamic and iterative learning and knowledge-centric mechanism as the core foundation towards resilient infrastructure systems. We have established, through evidence and arguments, that knowledge and learning is a critical aspect that enables dynamic and flexible response mechanisms. HE system in India, a critical aspect of the knowledge delivery system, however, falls short of being dynamic and adaptive to the on-ground challenges, particularly on issues of resilient infrastructure.

In this section, we attempt to conceptualise an operational agenda that reimagines HE to internalise the concept of adaptive pathways and enables the building of specific capacities that are responsive to the resilient infrastructure challenge, including those related to the urban. We identify a set of driving principles that should define such an educational intervention. The goal of such a transformed HE system would be to build relevant knowledge, capacities, and agency to support the agenda of sustainable urbanisation and, by extension, resilient infrastructure systems. This would entail the development of substantial critical thinking together with reflexive and transformational pedagogical methods and modes of delivery. Given this understanding, we conceptualise these foundational principles along a structural frame of content, pedagogy, and delivery – key constituents of the education system.

5.1. Content

Firstly, we argue that given disaster risk and urban challenges, including those linked to infrastructure, do not follow disciplinary boundaries, an interdisciplinary perspective towards content is a crucial first step. This perspective needs to be fostered through a mechanism that integrates teaching, learning and on-site practice. However, as noted from the previous sections, this is impossible to deliver and achieve in the current context – partly guided by an inadequate and insufficient understanding of the context in which we find disaster risk to exist; together with an absence of a critical engagement with the urban site and its context (of poverty, inequality, and other developmental issues). This creates impediments in the evolutionary process of developing an ability to problematise thereby leading to a potentially inadequate understanding of the 'solution' space . Given this, a critical step towards an interdisciplinary approach would require the creation of an institutional space that, by design, works on the principles of interdisciplinarity. For instance, the Urban Fellows Programme at the Indian Institute for Human Settlements (IIHS)[3] mainstreams interdisciplinarity by

prioritising conceptual elements, not disciplines, and using a 'site or a running case' as site of integration. This framing allows for exploring and building critical capacities, enables the bridging of theory and practice, and allows for propositions to emerge organically through the learning process, but deeply responsive and reflective of the context. This pedagogical innovation facilitates embedding interdisciplinarity structurally into the program and thereby, pursuing critical reflective capacities as the primary goal to pursue (Bazaz & Parnell, 2021).

Secondly, with respect to content, we argue for organising a learning framework that is dynamic and enables a continuous and systematic exchange of knowledge across multiple learning sites, for example, across classrooms and sites of intervention. Formal HE system is structurally inhibiting the creation of such dynamism and thus contributing to creating inadequate knowledge-based capacities. For instance, learning and knowledge generated through the implementation of the Smart City Mission in India, one of the flagship urban development programmes, provides an excellent repository to appreciate the complex realities of the urban in the Indian context. However, this is rarely leveraged to emphasise reflection and thus remains an untapped potential for multiple pathways of learning. What is more interesting in such examples is to focus on navigating bottlenecks and failures. A reimagined content, being deeply reflective, is interdisciplinary in structure and also, offers substantial learning opportunities. For instance, in educational and training programmes offered by research and teaching institutes like IIHS, Sierra Leone Urban Research Centre (SLURC),[4] and the African Centre for Cities (ACC),[5] that are at the forefront of interdisciplinary research in 'the urban' and located in the Global South, the extensive emphasis on immersive training and co-learning as important methods to teaching and knowledge creation is noteworthy (Bazaz & Parnell, 2021).

5.2. Pedagogy

In line with the argument for bridging the theory-practice divide and in relation to pedagogy, we argue for greater integration of practice and site-based learning. This, by design, is structurally interdisciplinary, closer to the context and via the goals of problematisation, allowing for prioritising critical reflection as a dominant form of knowledge accumulation. This would enable a departure from disciplinary lock-ins, expose the learner to tacit and field knowledge and emphasise the importance of context as a key arena of 'solutioning'. HEIs can leverage their own research and practice engagements to mainstream interdisciplinary problematisation, problem-solving and context-specific learning (e.g., Practica and case-based learning components that are part of the IIHS' curriculum). Similarly, HEIs can use the process of 'co-learning' – an immersive exercise that positions the learning and its context against dominant analytical principles – to theorise complex questions. Such a process enables the co-creation of shared conceptual categories that are, by design, deeply interdisciplinary.

5.3. Delivery

With regard to operationalising the above discussed content and pedagogical perspectives, our research thus far informs two learning pathways around resilient infrastructure issues. Recognising the fact that it will be premature to dismantle disciplinary biases in existing HE systems over a short-medium term, we envisage exploration of a neutral space (a Centre of Excellence or a subsidiary institution or a new programmatic intervention/course) that is used as a starting experimental site to test new ideas around content and pedagogy. This allows for experimenting with alternative models of institutional internalisation without having to rethink existing disciplinary curricula. Multidisciplinary learning could be facilitated within HEIs that host multiple disciplines, and for HEIs which are single-discipline oriented, a network of HEIs that facilitates knowledge exchange across disciplines could be facilitated, forming a foundational basis for interdisciplinary learning in the future. We may also explore experimenting with new institutions, e.g., the Coalition of Disaster Resilient Infrastructure (CDRI), to facilitate and anchor content and innovative pedagogy. A new institution, which is interdisciplinary in nature, allows for the seamless integration of adaptive pathway aligned principles of learning. Such institutions, like CDRI, would be best placed to facilitate knowledge exchange and learning through the testing of new pedagogical ideas like blended learning or dedicated fellowships. Such new experiments have been initiated and offer the best chance to bring together the agendas of resilient infrastructure, adaptive pathways and learning pathways.

6. Conclusion

In this paper, we start by underscoring the importance of adaptive pathways as a crucial conceptual pivot that helps in understanding and delivering resilient infrastructure systems. Adaptive pathways in its conceptualisation incorporate stakeholder participation and flexible and progressive implementation of actions, depending on how the future unfolds (Werners et al., 2021). This consideration of uncertainty and embedded feedback mechanism

becomes integral to conceptualising and planning for resilient infrastructures.

We have also, in this paper, articulated that knowledge and learning are key components of adaptive pathways that allow for this flexibility and dynamism. Knowledge exchange and learning that takes place through education (both formal and informal) play a critical role in building the capacity to identify root causes of complex urban issues and to rethink responses to address these. This, in turn, would enable the creation of resilient infrastructure systems.

We have focused on HE, a key component of the formal learning system. We have also examined informal learning spaces, such as learning from practitioner experience. Our emphasis was more on HE given its role in preparing learners for the job market while also providing the best institutional opportunity to internalise interdisciplinary learning. In that, it equips a new generation of urban practitioners and policymakers by influencing knowledge, skills, and attitudes, to deliver on the resilient infrastructure challenge.

Our research revealed that the HE system in India, in its current configuration, is strongly discipline-bound and falls short of teaching about the complexities of urban areas, sustainability and climate change. For instance, while technical, design and managerial aspects of urban infrastructures are taught in engineering, architecture, planning and management programmes, they are seldom situated within the larger context of the urban and the challenges posed by urban such as informality, poverty, and other development issues. An appreciation of urban and its complexities and recognition of uncertainty surrounding environmental change is pertinent to understanding urban infrastructure systems and disaster-resilient infrastructures.

We recognise interdisciplinarity as the key organising principle because it fosters substantial critical thinking and reflexivity, provided transformational pedagogical methods are adopted and innovative modes of learning are conceptualised and implemented. Three key elements – content, pedagogy and learning formats, within the broad architecture and principles of interdisciplinarity were identified. These are fundamental for HE to be used as an important lever to cultivate new knowledge, skills, and capacities to mainstream principles of adaptive pathways in the context of resilient infrastructure systems.

Interdisciplinarity highlighted above should get reflected in the elements of content, pedagogy and learning formats that prioritise conceptual categories such as adaptive pathways, not discipline, and enable the continuous exchange of knowledge across multiple learning sites, allowing for greater integration of practice and site-based learning. This, we believe, will foster the building of critical capacities, enable the bridging of theory and practice, and allow for propositions that are responsive and reflective of changing contexts. It also allows for response and reflection to emerge organically through the learning process. Operationalisation of such imagination in the context of HE would require an institutional space that, by design, fosters and mainstreams principles of interdisciplinarity.

We conclude by examining the characteristics of sites and innovative learning spaces that could be built on the key organising principle of interdisciplinarity, with the three defining elements (content, pedagogy, and learning formats) embedded into the learning and knowledge framework. We argue that existing HEs are unsuitable for such experiments because of strong disciplinary biases and rigid institutional structures and therefore a standalone institutional intervention catering to specific knowledge requirements should be imagined. In the case of India, for example, an institutional space embodied by CDRI could be a potential neutral site that institutionalises knowledge and learning in the domain of resilient infrastructure systems.

Notes

1. Specialised programmes – Programmes explicitly focussing on themes of climate change, climate risks, disaster risks, disaster management.

   Core course – Topics/ modules included in the compulsory courses offered by a programme.

   Elective Courses – Topics/ modules offered in the range of optional courses in a programme.
2. A studio is a pedagogic tool more prevalent in architecture and planning schools wherein students work on a design brief either chosen individually or directed by faculty. Studios draw on a multitude of learnings that cut across disciplines; further, it also provides a space for students and faculty to discuss topics and themes that are not traditionally included as part of the curriculum- for instance, climate change and disaster risk.
3. The IIHS Urban Fellows Programme is an interdisciplinary programme that combines classroom teaching, case-based learning, Practica (site-based learning), and hands-on work on live projects to guide interdisciplinary teaching and learning.
4. See Master's programme on Development and Planning in African Cities which is being jointly developed Sierra Leone Urban Research Centre and the Bartlett Development Planning Unit at University College London
5. See M.Phil in Southern Urbanism programme offered by the African Centre for Cities

Competing interest declaration

One or more of the author(s) is an employee of The Coalition for Disaster Resilient Infrastructure (CDRI), the sponsor of the article's Article Publishing Charge (APC).

Disclosure statement

This work was undertaken as a collaboration between the Indian Institute for Human Settlements (IIHS), The Bartlett Development Planning Unit, University College London, and the Coalition of Disaster Resilient Infrastructure and was supported by the British Council's Going Global Partnerships Exploratory Grant- 877,743,201. The Coalition for Disaster Resilient Infrastructure (CDRI) had no role in the peer review process nor the final editorial decision.

Funding

This work was supported by the British Council [877743201].

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