

Climate-U

Transforming Universities
for a Changing Climate

**How are universities
responding to the
challenges of the
climate crisis?
A systematic review
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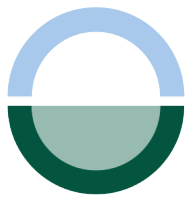
Transforming Universities
for a Changing Climate
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Charlotte Nussey,
Lorena Sanchez Tyson,
Ketan Dandare,
Joy Perry,
Tristan McCowan

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Charlotte Nussey, Lorena Sanchez Tyson, Ketan Dandare, Joy Perry and Tristan McCowan
August 2023

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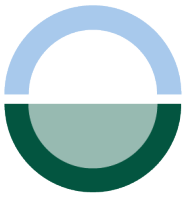
Abstract

Universities around the world have significantly expanded their range of activities in response to the climate crisis. Yet these actions are not always supported by an adequate evidence base. This report presents a systematic review of peer-reviewed literature on university actions in response to climate change published in English between 1990 and June 2020 in the Web of Science database. A total of 151 articles fulfilled all of the review criteria, and were synthesised according to five categories: education, knowledge production, community engagement, public debate and campus operations. The review makes two principal contributions: first, through thematic mapping of this published literature, it highlights the concentration of work in the Anglophone Global North, and thematically focused on explorations of education, campus operations and diverse forms of community engagement. Our search criteria revealed far less published which reflected on the research and public engagement functions of the university. Second, through synthesis of the substantive findings of empirical studies, it contributes an original typology of change, offering a holistic framework to understand the evidence that we have from these studies of university responses to the climate crisis. This framework highlights the role of universities in developing epistemic, ethical, behavioural, institutional, structural and atmospheric responses to the crisis.

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1.0 Introduction

Higher education institutions (HEIs) around the world are increasingly aware of the pivotal role they play in addressing the climate crisis. They are key institutions in generating the basic science to understand the causes and impacts of climate change, in forming professionals to play transformative roles, in providing information to the public, and in leveraging policy change. While many of these initiatives are developed 'bottom-up', through the commitments of individuals and groups in the staff and student body, university leaders are taking greater interest in galvanising their institutions' positive impact in relation to sustainability, and in bringing synergies through the various activities. This review aims to support such work by providing a systematic account of the body of evidence which exists.

While there is existing work reviewing universities and sustainable development, or climate change and education (generally interpreted as schooling), there has not yet been a systematic gathering of the evidence of the work of universities to respond to the climate crisis specifically. This review has been conducted as part of the Global Challenges Research Fund (GCRF) project Transforming Universities for a Changing Climate (Climate-U), which aims to strengthen the role of universities in climate action across a range of contexts in Africa, Asia, Europe, Latin America and the Pacific.

The role of research and innovation in addressing climate change is widely acknowledged, and universities, though to differing degrees across the global landscape, are closely involved in the tasks of monitoring, interpreting and responding to the process and impacts of climate change. Yet the broader role of universities in responding to the climate challenge is as yet under-researched. This systematic review is interested in exposing the gap in our knowledge in order to answer the following question: "How are universities responding to the challenges of climate change?"

In answering this question, this systematic review provides three related but distinct contributions to academic knowledge. First, it captures the global distribution of literature to date, asking which topics, methods, countries and regions predominate and how, and which areas have been neglected, as well as if and how themes and regions align. Second, through synthesis of the substantive findings of empirical studies, it generates a global picture from the kinds of work universities are doing in different contexts across five different modalities of the university: education, knowledge production, community engagement, public debate and campus operations. The third original contribution of this review is to generate a typology of change from these mapping and synthesis exercises, presenting a visual that encapsulates the strength of evidence for the effectiveness of different forms of university responses to the climate crisis, across these five different modalities.

We consider that this review will be of interest to three related sets of stakeholders, in addition to those involved in academic research. The first, most obviously, are those whose work

considers university responses to climate change, whether as academics, students, or university staff members working in, for example, sustainability offices. The second set of stakeholders are those who are associated with funding bodies and donor agencies, for whom questions of evidence and what is missing in our understandings of university responses to the climate crisis will be of importance. The third set are those working in the policy space, whether institutional policies, national or regional policies. For these actors, we hope that the findings of the review will help to understand the important role that universities can play, setting out where and how the evidence is strongest for the impact of higher education institutions. Education as a sector is often left out of policy discussions related to the climate crisis, and we hope that this review will start to challenge some of the assumptions that leads to that omission.

This report is divided into seven parts. Following the introduction, the terms and scope of the review are clarified with an underpinning conceptual framework of five university modalities that sets out how we understand 'responses' to the climate crisis, and how this understanding shaped the search terms used, as well as the structure of the report. In part three, we summarise previous systematic reviews, and show how this report sits in dialogue with two existing bodies of literature which consider universities and sustainability or sustainable development, or which review literature on climate change education more broadly. In part four, the methodology for this review is outlined, giving the detail of the process by which we reviewed articles published in English in the Web of Science database between 1990 and June 2020, when the database searches for this review were conducted.

In parts five, six and seven of this report the main findings of this review are presented. Part five includes a mapping of the studies, by date and journal of publication, geographical focus, methodology and theme. In part six, a synthesis of the articles is offered, thematically divided into five modalities, and with reflection on the connections (and disconnections) between them in the literature reviewed. Finally, in part seven of the report, the typology of change which we have generated through this systematic review visualises the strength and concentration of the evidence for university responses to the crisis, and critically engages with broader questions of impact and outcomes. The report ends in part eight with our concluding reflections on the implications of this work.

2.0 University responses to the climate crisis: terms and scope

A key part of the process of a systematic review is that assumptions and implicit beliefs included in the conceptual framing of the review are challenged, and terms are clarified (Gough, Oliver, and Thomas 2017, 109). Two key concepts are thus important to engage with for the purposes of this work: what do we mean by 'universities', and what do we mean by 'climate change'. We then

conceptualise how we understand the relationship between them – i.e., what does it mean for a ‘university’ to ‘respond’ to ‘climate change’? To provide an answer to this question, we introduce the guiding conceptual framework that this systematic review draws on throughout, that considers university responses to the climate crisis through five different modalities or functions of the university: education, knowledge production, public debate, community engagement and campus operations.

2.1 Defining ‘universities’

This systematic review is focused on universities. The term ‘university’ is understood in a broad sense to cover not only research-intensive institutions, but also teaching-intensive and non-traditional higher education institutions such as open or online universities. The review covers both public and private institutions. Where the information is available and relevant to the synthesis, the types of institution are differentiated, for example, if an institution is public with a mandate that shapes its community engagement work. The type of institution, however, is not part of the systematic synthesis as in many cases this information was not included in the articles reviewed. It is also important to note that while we intended for the definition of universities included in this systematic review to remain open, our focus on empirical studies in peer-reviewed journals (as discussed in more detail in part three of this report) means that in practice the majority of studies reviewed were generated by research-intensive institutions.

While ‘tertiary education’ was used as a search term, this review is concerned with studies in HEIs that include teaching at UNESCO’s ISCED level 6 (equivalent to Bachelor’s degrees) to level 8 (equivalent to doctoral studies) (UNESCO 2012). Empirical studies which focus on interventions at post-secondary but at a lower ISCED level were therefore manually excluded at the screening stage; analysis of these exclusions can be found in part four of this report. Vocational education and training (VET) colleges, as well as other forms of further education, were also manually excluded from this review, but we recognise that they would be an important site for further research.

2.2 Defining ‘climate change’

Following the definition first established in the United Nations Framework Convention on Climate Change (UNFCCC), this review understands climate change to be both direct and indirect anthropogenic interference with the climate system (UNFCCC, 1994, Articles 1 and 2). Building on this definition, common language around climate change such as in the targets of SDG 13 (“to take urgent action to combat climate change and its impacts”) builds the focus to limiting global warming through emissions of greenhouse gases, and includes language such as ‘resilience’, ‘adaptation’, ‘mitigation’, ‘emissions reduction’, ‘impact reduction’ and ‘early warning’. Trial searches of terms

conducted using Google Scholar during the early phases of planning for this review, however, suggested that where these more specific terms around climate change are linked to work by HEIs, the term ‘climate change’ is also used in the title or abstract of studies or as a key word. The review did not, therefore, search for these more specific terms separately. We did, however, search for ‘global warming’ as a common synonym for climate change. The search terms also included ‘campus’ in addition to ‘university’, ‘higher’ and ‘tertiary education’ in recognition of the prevalence of literature on ‘greening the campus’ and other related topics that may not include a direct reference to universities, higher or tertiary institutions in their title or abstract. The Boolean search terms used are provided in Appendix 1.

A second important focus of the literature on climate change focuses on climate-related hazards, extreme weather and natural hazards, with related terms around ‘preparedness’, ‘risk’ and ‘vulnerability’. Given the size of the literature on disasters, the majority of which may be attributed to climate change either in cause or severity, this review did not include searches for either ‘natural hazards’ or specific disasters such as ‘cyclones’, ‘drought’ or ‘flooding’ as separate research terms. Geological hazards, including earthquakes, tsunamis and volcanic eruptions were also not of specific interest for this review. Where literature focuses on the role of higher education and the specific relationship with climate change and climate-related disasters, however, this literature is expected to be captured by the two main search terms. We recognise this as a potential limitation to the review, as discussions of dis/connections between climate change and disaster-risk reduction literature has highlighted that these two bodies of literature are often seen as distinct (Kitagawa 2021). A further review focused on university responses to climate-related disasters would be an interesting site for future research and a useful complement to this paper.

Finally, it is also worth noting that the authors are cognisant of the ways in which ‘climate change’ is itself a contested term, and that the language which we use to describe the crisis is deeply politicised. Increasingly, academics working on questions of ‘climate change’ with a socio-ecological justice lens are turning to the language and ethics of climate justice in their work. A recent review of this work usefully explores ways in which a gap exists between academic and activist framings of climate justice (Newell et al. 2021). In this review, Newell and colleagues refer to ‘cognitive’ and ‘epistemic’ forms of justice, associated with awareness and knowledge, particularly for indigenous and marginalised groups, but outside formal educational institutions. Newell et al. (2021) thus do not reference any work that specifically discusses universities, although they do acknowledge work around the need for ‘transgressive learning’ in times of climate change (Lotz-Sisitka et al. 2016). Questions of where and how articles within this systematic review engage with questions of justice are discussed in the conclusion of this report.



2.3 Guiding conceptual framework: university responses to the climate crisis

An important clarification for the scope of this systematic review is that we do not aim to cover every form of interaction between universities and the climate crisis. There is an important body of literature captured by the research terms, for example, that focuses not on ‘responses’ of universities to climate change, but rather the ways in which higher education institutions themselves have contributed to the climate crisis, such as through academic mobility of staff and students leading to increased emissions, or through involvement in colonial and industrial development. These studies were outside the scope of the review, but represent an important part of the scholarship understanding the relationship between higher education systems and the climate crisis.

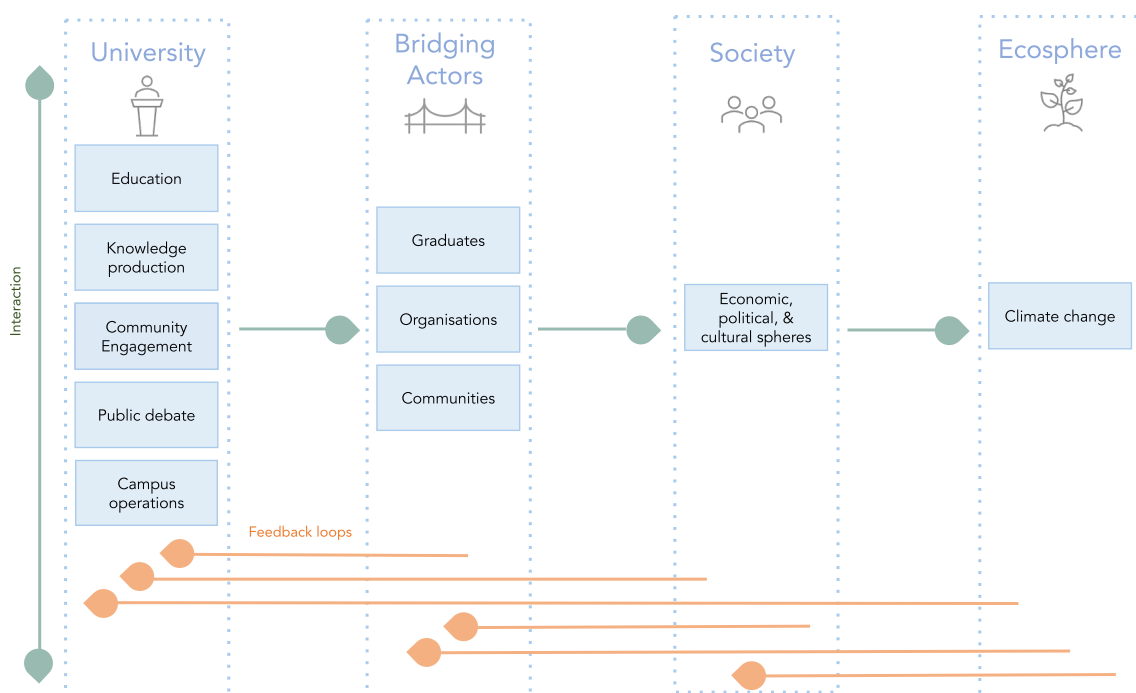
A second key point on scope is that this is not a review of all relevant activities currently underway in universities – we are not aiming to provide a list of different courses offered on climate change, nor are we aiming to discuss the content of research, for example the physical science basis for understanding the crisis, even where this science is undertaken by actors within HEIs. While research to explore the intensity and patterns of the climate crisis is in one sense a ‘response’ to the climate emergency, it falls outside the remit of this review, which focuses on published literature on the university itself. Furthermore, a review of all climate research would be a huge undertaking requiring extensive technical expertise, and is already covered by the remit

of the Intergovernmental Panel on Climate Change (IPCC) (for their most recent report, see IPCC 2021-2022). Nevertheless, many studies focused on climatology were captured by the search criteria; analysis of how these studies were excluded can be found in part 4.5.2 of this report. Furthermore, our methodological decision to not include ‘research’ as a separate search term (because this would have produced a prohibitively high number of studies) will have inevitably shaped the smaller number of studies reflecting on the knowledge production function of the university. We reflect on this in more detail in the synthesis which follows.

This review thus covers meta-reflections that draw on empirical research, and which provide evidence of impact through these university interventions or responses to the crisis. In order to synthesise these articles and understand in more depth the different functions of HEIs, we draw on McCowan’s (2020, 9) conceptual framework (figure 1, below) of the impact of universities on climate change, which itself builds on previous theoretical framings of the development impacts of universities (Oketch, McCowan, and Schendel 2014; McCowan 2019).¹ As figure 1 (below) suggests, this review focuses on five modalities of university action: education, knowledge production, community engagement, public debate and campus operations. Part seven of the report, in generating the typology of change, engages not only with the five modalities of the university but reflects on how different forms of evidence of university responses relate to the three columns on the right of the figure: bridging actors, society and the ecosphere.

1 In doing so, we slightly modified the original framework presented in McCowan (2020). ‘Community engagement’ in this paper replaces ‘service delivery’ in the 2020 paper, in order to better fit the terminology in the literature reviewed in this report.

Figure 1. A framework of university impact on climate change



For the purposes of this report the 'education' function of the university has been divided into three sections, one focusing on 'curriculum', covering the aspect of knowledge content and the inclusion of climate change in university courses, one focusing on 'pedagogy', involving discussions of teaching and learning, and one on 'teacher education' specifically. We, of course, recognise that these are porous divisions, and connections between the sub-sections of the education modality are acknowledged in the synthesis which follows.

As regards the other modalities, we understand the 'knowledge production' function of the university to be through reflection on the generation of knowledge, including meta-reflections on research agendas. This modality could also include university responses to government or industry needs, or the development of new forms of technology or innovations aimed at responding to the crisis, e.g., through carbon capture, although neither of these interpretations appear in the literature that forms part of this review. 'Community engagement' covers activities of the university with diverse external communities (including government, private sector, civil society organisations and local community), as well as communities within educational systems such as primary and secondary schools. 'Public debate' includes the participation of staff and students in debates around the climate crisis in the broader society, such as activism, mobilising and campaigning, as well as the influence of external legal and media discourses on the work of those inside HEIs. Finally, 'campus operations' refer to responses in the management and activities of the university as place, both in terms of physical and policy infrastructure, which we have defined as greening and governance respectively.

We have called this a 'guiding' conceptual framework, because the aim of the review is in part to flesh out ways in which this framework is represented in the literature reviewed: we were interested in the balance of articles represented by each of the five modalities or functions of the university. During the thematic mapping which is detailed in part five of this report, we identify where the concentration of evidence lies. In Appendix 5, a thematic coding summary table is given, which details how we have coded each article reviewed, with crossovers between the different modalities included.

3.0 Climate change education, universities and sustainability: previous relevant reviews

As part of the first stage of writing this report, previous relevant systematic reviews were searched for (the details of which are given in Appendix 2). Two related bodies of literature were identified through this process: reviews considering universities and sustainability or sustainable development, and reviews

considering climate change education. No previous systematic reviews were identified which focus on higher education and the climate crisis specifically.

Eight previous reviews – whether systematic, comprehensive or in-depth – were found to consider sustainability and higher education. This is not surprising: sustainable development, and in particular the internationally endorsed formulation contained in the Sustainable Development Goals (SDGs), has become a focal point of higher education in recent years. A number of universities have adopted the goals as an orienting framework for their work, or mapped their existing activities in relation to them, and there has been a corresponding increase in research articles on the topic.

Wu and Shen (2016) focused on literature on sustainability education in higher education within four scientific literature databases (EBSCO, ProQuest, ScienceDirect and Emerald) and "broadly within the academic literature published during the DESD²" (Wu and Shen 2016, 635), ultimately reviewing 454 articles published between 2005 and 2014. They found that while there was a broad set of research on the environmental and economic perspectives on sustainable development, there was a paucity of research that explored the socio-cultural dimensions. This finding was of particular interest to us, given the socio-cultural nature of education.

Findler et al. (2019) systematically reviewed peer-reviewed journal articles published between 2005 and 2017 on the topic of the sustainable development impacts of HEIs on their stakeholders, the natural environment, the economy and society. In their synthesis of 113 articles, the authors suggested that the "impacts of HEIs on sustainable development remains relatively fragmented, and spread over a wide range of journals" (Findler et al. 2019, 27). An earlier systematic review conducted by Ceulemans, Molderez, and Van Liedekerke (2015), in this case bringing together 178 articles on sustainability reporting (SR) in higher education published between 2000 and 2014, found through their content analysis that the topic of SR "has been approached in a rather fragmented way" but argued that an important topic for further research is the potential for organisational learning, and the development of an indicator for SR within HEIs. Also focusing on questions of indicators, Karatzoglou (2013) offered an in-depth literature review of the work exploring HEIs as regional hubs for sustainability, reviewing 123 articles published between 2003 and 2011. He found that very few case studies presented in articles describe the metrics used to measure the 'success' of HEIs as regional hubs, and argues that scorecards need to be conceptualised. These questions of the fragmentation of the literature, as well as metrics for success, are considered in parts five to seven of our own findings.

In a review that focused primarily on the education function of the university and the relationship with sustainability, Wiek, Withycombe, and Redman (2011) conducted a 'broad' literature review around key competencies in sustainability for graduate

2 United Nations Decade of Education for Sustainable Development



students based on 43 primarily peer-reviewed journal articles and books.³ Based on their review they argue for five key competencies: systems thinking competence, anticipatory competence, normative competence, strategic competence, and interpersonal competence. Questions of competencies, complementing these findings, are returned to in part six of this report, in the synthesis of articles focused on the education function of the university.

A comprehensive literature review conducted by Amaral et al. (2020) on the actions and initiatives implemented in university campuses to reduce their environmental impact, focused exclusively on scientific documents published since 2010 and used key words 'sustainab*', 'university' and 'campus' (Amaral et al. 2020, 4). They found that only 120 of the 357 studies retrieved focused on practical activities and empirical data, and so also included a review of 112 articles presenting universities as case studies. Amaral and colleagues found that the most common policy of universities was increase in campus-based energy generation, which they attributed to the shorter-term impact of these policies. They also noted that investment in sustainable and green energies and building were more common initiatives in HEIs within higher-income countries. Questions of the 'campus operations' function of the university are discussed in the final part of the synthesis in this report, while the typology of change considers the number of studies which focused on measurements of energy reduction.

Another systematic review of sustainability in HEIs conducted by Bizerril et al. (2018) focused on Portuguese speaking countries, following the framework offered by Lozano et al. (2015) that considers seven dimensions of the university that relate to sustainability: education, research, operations, outreach, on-campus experiences, institutional framework and assessment and reporting. A total of 50 articles and conference proceedings published in the social sciences and humanities until December 2015 were analysed (Bizerril et al. 2018, 603–4). Bizerril et al. argue that the specific contribution of Portuguese-speaking countries is through the tradition of 'extension' in Brazil, as well as the democratising focus around sustainability and HEIs, shaped by the ideas of Portuguese-speaking theorists Freire and Santos. Questions of extension, this time in the context of the USA, are discussed in part six of this report, under the 'community engagement' function of the university.

Vaughter et al. (2013) reviewed 117 empirical studies published in English between 2003 and 2012, with a focus on comparative or multi-sited work.⁴ The authors considered any studies to be empirical if they focused on quantitative or qualitative collected data, with a focus on two or more institutions. They found that there were three broad areas of interest: research comparing sustainability curricula; research comparing campus operations (in terms of both policies and practice) and research on how to best measure or audit approaches. In terms of curricula, Vaughter et al. found that there was much less work that paid attention to the humanities and social sciences than the 'hard' sciences and engineering. In terms of audits and campus operations, they found that there were

research gaps around how institutions' sustainability operations link to broader communities, and that measurements tended to focus on quite narrow conceptualisations of institutional 'outputs', that tended not to include education or governance.

As a focused systematic review that is looking at responses to climate change, this review thus sits within a much broader set of literature that explores the role of universities within education for sustainable development. This 'nested relationship' (Molthan-Hill et al. 2019, 1093–94) between the responses of universities to climate change and their role in education for sustainable development is an important context for the review. At the same time, the simultaneous breadth and potential fragmentation of this field that is identified by Wu and Shen (2016), Ceulemans et al. (2015) and Findler et al. (2019), as well as the absence of specific focus on climate change in systematic reviews conducted on higher education so far, highlights the importance of a focused review on the responses of HEIs to climate change that excludes this wider literature. This systematic review did not, therefore, use 'sustainability' or its cognates as part of its search terms.

In addition to these eight reviews focused on universities and sustainability, three reviews considered the climate crisis and climate change education more broadly, with some discussions of relevance to higher education. The first of these was unusual for its focus on indigenous knowledge systems, while a second two were more concerned with climate change education in both schools and universities.

In their systematic review of the ways in which indigenous knowledge systems (IKSs) are deployed in climate change adaptations, Mbah, Ajaps and Molthan-Hill (2021) screened a total of 39 publications from two databases (Web of Science and ProQuest). Using an inclusion criterion of peer-reviewed journal articles in English between 2010 and 2020, the authors found that indigenous knowledge holders are employing a range of climate change adaptation strategies (categorised in the article as social, structural, and institutional adaptations) to reduce vulnerability to climate change. In addition, they argue that the integration of IKS and 'critical, place-based, participatory, and holistic methodologies' within and across such strategies is necessary for effective processes of decolonisation in climate change education (Mbah, Ajaps, and Molthan-Hill 2021, 16). While the authors discuss implications of their review for climate change education across systems and curricula in 'developing world contexts' (p. 1), they do not go into further detail about climate change education at universities specifically.

Another systematic review of research aimed at identifying and understanding effective climate change education strategies was Monroe et al.'s (2019) study. The inclusion criteria by which the authors included the final 49 studies were peer reviewed journals in English from the database EBSCO which specifically assessed educational interventions and empirically measured and reported results. Most of the interventions included in the review involved

3 The dates of publication are not specifically given by the authors, but the work cited is published between 2000 and 2010.

4 Their work drew on systematic methods, but did not describe itself as a 'systematic' review.

those at a primary or secondary school level. Nonetheless, eleven studies were linked to interventions at universities, e.g., by analysing a part of a course or entire courses as we do in the curriculum synthesis which follows (part 6.1 of this report). The authors suggested six themes that contribute to effective climate change education: (1) personal relevance, (2) engaging students, (3) deliberative discussions, (4) interaction with scientists, (5) addressing misconceptions, and (6) implementing school or community projects (Monroe et al. 2019, 801).

Similarly, Rousell and Cutter-Mackenzie-Knowles's (2020) review of climate change education for children and young people analysed literature published between 1993 to 2014 available on Google Scholar. A total of 220 articles in English were analysed across five categories, namely (1) geographical location, (2) date of the publication, (3) contextual focus, (4) discipline, and (5) the approach to climate change education (Rousell and Cutter-Mackenzie-Knowles 2020, 193). The systematic review aimed to 'establish the topography of existing climate change education research' with a stated focus on the relevance of climate research to children and young people (p. 192). To do so, they used a broad-based approach to include research in schools and universities as well as research in more 'informal' settings (e.g. at museums and community events). The results of the analysis suggested that tertiary education dominated the climate change education research landscape. Moreover, the authors found that the dominant approaches in the field of climate change education continue to be those which are science-based and within formal education settings. As a result, they called for more integrated, participatory, and creative cross-disciplinary approaches to climate change education.

Our review thus sits in dialogue with both climate change education and universities and sustainability, but with a specific interest in HEIs and the climate crisis that connects these two bodies of literature. The following part of this report sets out the methodology of this review, making explicit our process, and detailing the stages of the review from developing the conceptual framework discussed above, to conducting the screening by text and abstract and subsequently full text, before mapping and synthesising the studies.

4.0 Methodology of the review

In any systematic review, difficult decisions need to be taken in order to balance the comprehensiveness of coverage with the practical possibilities of the work undertaken, in a manner that is coherent and transparent. This review adopted a pragmatic approach, restricting the synthesis to articles contained in the Web of Science database. While this database represents only a part of all global output, and is dominated by 'elite' English-language journals, the restriction served the purpose of providing an easily searchable database and a selection of studies of a manageable size. Furthermore, while much research of quality is not contained within the Web of Science database, it can be seen

to represent a minimum level of quality of journals, given the stringent requirements for entry into the index, and the practice of peer review. In addition, it allowed us to assess the treatment of the topic within the most globally recognised research output, and to evaluate some of the limitations of the current publication landscape. This report thus reviewed literature published in English in the Web of Science database between 1990 and June 2020 (when the searches were conducted). Parts 4.5-4.6 of this part of the report give the detail of screening these articles, a process which is summarised in figure 2.

4.1 Scoping phase

Test searches were initially conducted in four databases: the Web of Science, SCOPUS, SCIELO and ERIC. Given the focused nature of this systematic review, the search strategy aimed to be exhaustive, aspiring to access every relevant study within the reviewed databases, to not only reach 'conceptual saturation' but review a broad body of evidence (Gough, Oliver, and Thomas 2017, 119). The rationale for including these four databases was to focus on the two main selective journal databases (Web of Science and SCOPUS), supplemented by selective databases with a focus on publications in Portuguese and Spanish (SciELO), and educational journals (ERIC).

Our initial searches in the SCOPUS database returned more than 10,000 articles. This very large number was the result of an indexing quirk which meant that articles including our main search term ('university') in their copyright were also returned. Since these articles were not otherwise focused on the work of universities, they would have needed to be manually excluded (discussed in more detail in part 4.5 of this report, below).

Given the global nature of climate change, the original intention for this review had further been to include articles published in English, French, Portuguese and Spanish, aiming to address (albeit only to an extent) the language-based publication bias (Gough, Oliver, and Thomas 2017, 122). These three languages were spoken by the review team and represent the dominant *linguae francae* in Africa and Latin America, the two regions which – along with Fiji which uses English in higher education – are the focus of the broader Climate-U study of which this review is part. When the search results were returned however, most of the articles in the Web of Science were in English, with only three articles published in French, five in Portuguese, and 38 in Spanish. We tested supplementing this relatively smaller proportion by applying the search terms and language filters in two further databases: SCIELO and SCOPUS. This yielded a further 34 articles in French, 37 in Portuguese and 59 in Spanish which were imported into the software. This total of 176 articles published in French, Portuguese and Spanish still made up a relatively small proportion, however, of the total 2926 studies. Furthermore, at the end of full text screening, no articles in French, only one in Portuguese and five in Spanish met the inclusion criteria.



We therefore decided to exclude these articles at the synthesis stage, and to focus solely on peer-reviewed articles published in English. We recognise this linguistic bias as a limitation of the review and raise it as a question of the field more broadly. It is important to note that we cannot make a broad claim that work is not being published in French, Portuguese and Spanish on the topic of universities and the climate crisis, only the narrower claim that there is a relative paucity of publications in these languages (when compared to English-language publication) in the four databases and under the search criteria which we deployed.

At the end of the full-text screening, after the Spanish and Portuguese language articles were excluded, the total number of included articles (170) was further heavily weighted towards articles which were housed in the Web of Science database (151) with only 19 included articles housed in ERIC. Given the specific focus of ERIC on educational research, we decided to exclude these 19 articles so as not to provide a disciplinary skew, given that we had not conducted corresponding searches in other subject-based databases.

This review thus covers 151 articles published in English in the Web of Science database. The Web of Science is a research platform run by Clarivate Analytics⁵ providing access to a list of over 14,000 journals⁶. Entry to the list is based on the discretion of the platform, and dependent on a set of 24 quality criteria. Those journals included are issued with an annual journal impact factor, indicating rate of citation frequency. The index is both weighted towards English-language publications located in high-income countries as well as towards STEM disciplines. While we acknowledge the limitations of drawing from a single database to conduct the review, its usage was as a pragmatic tool, with Web of Science providing a readily accessible collection of peer-reviewed articles. Furthermore, as stated above, the purpose of this review was to interrogate the exclusivity in question, and to assess the biases at play in the portrayal of climate action in higher education globally.

The process by which screening was undertaken is documented in the following sections of this report, including the three relevance criteria pre-determined before searches were undertaken: date, geographic context and type of study.

4.2 Relevance Criteria

4.2.1 Date

The start date for this review was set at 1990, the year in which the first IPCC report was published. The end date for articles included in the review was June 2020, when the searches were conducted. In the end, however, our searches did not yield any articles published before 1990, and so there was no need to

apply this start date as an exclusion criterion. A table with dates of publication of the included articles is provided in part five of this report.

4.2.2 Geographic context

Given the global nature of climate change, and the international focus of the Climate-U project, the review was not limited by country or region. Following the Kyoto Protocol and widely acknowledged understandings of climate change, however, the review acknowledges that climate change results in “common but differentiated responsibilities and respective capabilities”: HEIs in the most industrialised countries may have different responses to those located in the poorest communities and nations, with correspondingly localised research and HEI responses to SDG 13 (Salvia et al. 2019). At the mapping and syntheses stages, therefore, articles were grouped by region as well as income – lower, middle and higher – following World Bank definitions. While we followed these more standardised regional categorisations when determining how many studies were associated with which region, we primarily make use of the designations ‘Global North’ and ‘Global South’ throughout the study to describe groupings of countries along similar political and socio-economic characteristics. These mappings are included in part five of this report. We also acknowledge that the decision to focus on studies published in English will have inevitable impact on the geographical spread of articles included in this review.

4.2.3 Type of study

This review focuses on empirical research. Theoretical studies were, however, captured by the search terms, as were descriptive histories and review articles. These studies were excluded from the main synthesis of this review. The rationale for this was not that we do not value theoretical work, but rather that the aim of this review was to capture evidence of practice. Beyond the criterion for an empirical basis to included articles, no studies were excluded on grounds of methodology. The review includes quantitative and qualitative research, as well as studies using mixed methods. A table of these methods is provided below, in part 5.4 of this report.

As a departure from standard systematic review procedure, the process of this review did not include a specific quality appraisal stage. The review assumes that articles published in the journals identified have already been appraised for quality during peer-review (though it is acknowledged that this assumption may not hold in all cases). Where the review captured book chapters and conference proceedings, these were manually excluded during the screening by title and abstract stage.

Furthermore, we recognise that much relevant research is

⁵ Prior to Clarivate Analytics, it was run by Thomson Reuters, having been originally produced by the Institute for Scientific Information.

⁶ 9200 in the Science Citation Index Expanded (SCIE), 3400 in the Social Sciences Citation Index (SSCI) and 1200 in the Arts & Humanities Citation Index (AHCI) – <https://clarivate.com/webofsciencegroup/solutions/web-of-science/>

published in journals and other outlets that are not listed in these databases, and that many established journals are dominated by voices from well-established higher education systems in the Global North. The small size of the review team precluded a global review involving all forms of literature such as reports, local journals, conference proceedings, PhD theses, and other grey literature; these forms of literature are thus not represented in this review, but do form the basis of other literature reviews at national levels conducted by other members of the Climate-U team published in our working paper series.

4.3 Stages of review

The process of conducting the systematic review involved five stages. The review was interrupted at various points due to the coronavirus pandemic, and different authors of this report contributed to different stages.

The stages of the review were the following:

- i. Development of conceptual framing and review protocol
- ii. Database searches and cleaning of reference list (e.g. removing duplicates)
- iii. Screening
 - a) by title and abstract
 - b) by full text
- iv. Mapping of studies
- v. Synthesis and final write-up of report

The structure of this report broadly follows the five different review stages.

4.4 Database searches

Following the search strategy above, and using the terms identified as an example in Appendix 1, our searches yielded 2926 references which were then imported into the online EPPI-reviewer⁷ software.

250 articles were identified as duplicates, either by the EPPI database automatic software, or through manual checks of the reference list throughout the screening process. A further 271 articles were deleted either because their abstracts or full text manuscripts were unavailable,⁸ or because they were book chapters, conference proceedings or published interviews (i.e. not peer-reviewed academic studies published in academic journals). The removal of these 521 articles left 2405 articles for screening.

During screening, the following exclusion criteria were applied:

- i. Does not focus on climate change
- ii. Solely reports on climate science
- iii. Not a university response to the climate emergency
- iv. No empirical findings

A description of how each criterion was applied is given below, followed by a table providing a list of how many articles were excluded under each criterion, first at the screening by title and abstract stage, and then during screening by full text.

4.5 Description & application of exclusion criteria

4.5.1 Exclude: Does not focus on climate change

Articles excluded under this criterion mentioned climate change amongst a string of problems facing humanity or the ecosphere but focused on an otherwise unrelated topic (e.g. the securitisation agenda in overseas aid). At the full text stage, articles were excluded when there were a few references to climate change within an article, but without a direct focus: for example, an article mentioned climate change in the introduction and conclusion to the article, but the main body of text and/or empirical evidence was speaking to a different topic. There were also a few articles excluded under this criterion which talked about 'climate change' as a form of institutional dynamic, for example, higher education institutions responding to the #MeToo movement, in a 'changing climate' of attitudes to gender.

4.5.2 Exclude: Solely reporting climate science

Most articles were excluded under this criterion. This criterion predominantly covered articles which were reporting on climate science conducted by HEIs, or which recommended further research at HEIs as an outcome of their climate science but were not otherwise a 'response' to climate change (as understood in terms of the conceptual framework outlined above, in part two of this paper). Some articles were taken to the full text stage if it seemed from reading the abstract that the article might contain a degree of reflection about the power dynamics or agendas behind climatology research, but were excluded when the full text revealed that the article was solely focused on reporting the findings of climate science.

⁷ EPPI-reviewer is software for conducting systematic reviews developed by the Evidence for Policy and Practice Information and Co-ordinating Centre (EPPI-Centre) at the Institute of Education, University College London.

⁸ By unavailable, we mean that the reviewing team were unable to source their full manuscripts either in University College London's online bibliography or through Google Scholar (and associated depositories, such as ResearchGate).



4.5.3 Exclude: Not a university response

Articles coded under this criterion all included some degree of engagement with the context of universities, but without a specific response to the climate crisis. Many of these studies were of potential interest for other dimensions of the Climate-U study, such as the survey of undergraduate students, or the role which universities might play in exacerbating as well as responding to the crisis. For this reason, these articles were sub-coded separately as an additional resource for future work.

Some articles (n=67) coded under this criterion discussed 'higher education' as a variable in relation to attitudes to climate change amongst members of the general population (as opposed to students), and asked questions of whether attitudes or behaviours varied depending on educational levels. If studies contained research both with members of the general population and with students, these were sub-coded as related to students.

A larger sub-set of studies (n=159) coded under this criterion assessed attitudes to climate change of students, pre-service trainees (health professionals/teachers) or academic staff, but were only reporting on measurements of these attitudes about climate change, and did not include any actions taken in response to these attitudes by HEIs. Articles were also excluded here where university students were research subjects, for example in experiments on climate change communication, but without any institutional response as a result of the experimental findings. Where articles did signal responses taken in their abstracts, these were included for full text screening.

The third sub-set of these articles (n= 26) discussed emissions from academia, particularly around the mobility of students and academics, but also assessing the carbon footprint of HEIs themselves. Where assessment of these emissions led to a response by the university – for example by creating a carbon offsetting policy for flights of staff – these articles were included for full text screening. In most cases, these were measurements of current emissions, but a few articles also contained forecasts of future emissions from universities or staff.

The fourth sub-set of these articles (n=91) focused on assessing campus sustainability, often through energy efficiency of the full campus or a single university building, but did not detail any specific responses by HEIs in response to these assessments. Where articles did include both an assessment of emissions and also signalled responses taken, for example in the development of an institutional sustainability plan, or through actions to green the campus, these articles were taken forward to the full text stage.

The remaining studies excluded under this criterion (n=4) related to research that was happening outside HEIs or tertiary education, for example, work in vocational education and training, a community college in the USA, or a study in which a primary school in Ghana with an interest in climate change

education was named after the university, but where no other specific affiliation or substantive relationship with higher education was discussed within the article.

4.5.4 Exclude: No empirical findings

Articles excluded under this criterion were theoretical or normative treatments of HEIs and climate change, in addition to some systematic reviews of sustainability initiatives in universities. They also included a few articles arguing for pedagogical approaches to climate change, for example the use of artificial intelligence, but without any empirical data.

Articles were also coded under this criterion when they descriptively reported on a project, set of university courses or framework associated with climate change in HEIs, but without any explicit findings. We did, however, include articles which were based on the personal experience of the author, or which were based on documentary analysis, e.g. of institutional climate or sustainability policies. This distinction was sometimes harder to interpret, and so several articles which may have been descriptive rather than empirical were put through for screening at the full text stage.

4.6 Screening Summary

4.6.1 By title and abstract

2405 articles were screened by title and abstract, with a total of 2051 excluded, leaving 354 articles for full text screening. At the beginning of the process, a random sample of 35 articles was coded by all three members of the coding team, and application of the criteria was defined in detail. During the middle and end of the process, a random selection of 10% of articles was coded twice to ensure consistent application of the exclusion criteria, with more than 80% agreement.

4.6.2 By full text

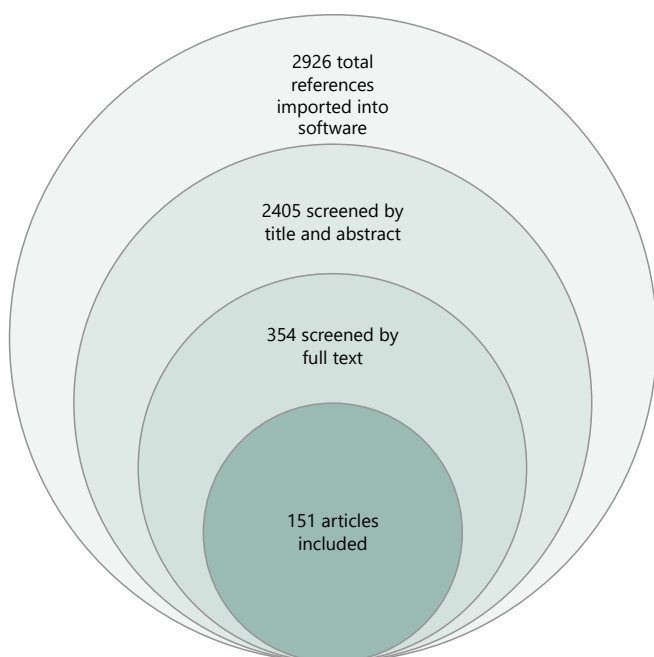
The screening by full text applied the same exclusion criteria to the remaining 354 articles as had been applied during screening by title and abstract. At this full text screening stage, preliminary inductive coding for the mapping of articles by geography, language, type of study and theme (discussed below in part five of this report) also began. Screening during this full text stage meant (to a degree) some refinement of the exclusion criteria, and so regular meetings were again held between the screening team to collectively define the approach to the application of the exclusion criteria. As at the title and abstract phase, 10% of articles excluded under each criterion were coded twice to ensure consistency. The following table summarises how many articles were excluded under each criterion at the two stages of screening.

Table 1. Application of exclusion criteria at each stage of screening

Exclusion criterion	Excluded in title & abstract screening	Excluded in full text screening	Totals
1. Not focused on climate change	97	66	163
2. Reporting climate science	1471	69	1540
3. Not a university response	343	4	347
4. No empirical findings	140	39	179
Total	2051	178	2229

The exclusion of 178 articles during full text screening left 176 included articles. As discussed above (in the first part of this methodology), however, this number included one article published in Portuguese and five in Spanish. It also included 19 articles published in the ERIC database. These 25 articles were also manually excluded, leaving 151 articles to be imported into a shared Zotero bibliography and taken forward for the more detailed mapping and synthesis which is discussed below. Figure 2 (below) summarises the methodological process of this review.

Figure 2. Methodological process of the review



After the exclusions discussed above, the 151 articles taken forward for synthesis were mapped using five overarching codes: date; journal of publication; geographical focus; methodological approach and university modality or theme (following the conceptual framework outlined in part two of this report). The following part of the report discusses this mapping, before offering a synthesis of the included articles in part six.

5.0 Mapping of studies

Mapping the included studies is an important first analytical step. This chapter discusses the six stages of mapping that we undertook. Each stage revealed useful information about the kind of studies included in this review, beginning with mapping over what time period, in which journals, and with what countries of focus articles about university responses to the climate crisis have been published. This chapter also sets out which methodologies the 151 studies deployed, whether quantitative, qualitative or mixed, as well as their specific methods, such as qualitative interviews, quantitative analysis of survey data or some form of combination. Another layer of mapping documents the dominant themes of each of the studies, following the five modalities outlined in our guiding conceptual framework, and which sets up the synthesis which follows (in part six of this report). The table in Appendix 5 brings together three of these dimensions, listing the references alphabetically with their countries of focus, methodologies and themes.

Finally, as the first stage of the original contribution of this systematic review, the mapping phase also revealed different ways of engaging with ‘evidence’ of university responses, with three inter-related uses of empirical data represented by the 151 studies reviewed for this report. This work to map evidence was used to generate a typology of change, which is introduced in the final part of this chapter.

5.1 Date of publication

Of the 151 articles included in the synthesis, the earliest article was published in 2003, with a further 13 articles from 2004-2009. Most articles were published after 2010, with increasing prevalence since 2017. Searches were conducted at the midpoint of 2020 (June), and so only 12 articles published in 2020 were included. This upward trend in publication in recent years may reflect broader processes of increasing numbers of articles in the Web of Science database in general. But it is also likely to reflect increasing attention to issues around climate change and its links to education, associated with increasing focus on climate and sustainability in education discourses associated with, for example, UNESCO’s Decade for Education for Sustainable Development (2005-2014) and the 2030 Agenda for Sustainable Development (2015-2030).



Table 2. Date of publication

Date of publication	Number of studies
2003	1
2004	1
2005	0
2006	1
2007	0
2008	3
2009	7
2010	3
2011	4
2012	5
2013	5
2014	12
2015	12
2016	14
2017	23
2018	24
2019	24
2020	12
Total	151

5.2 Journal of publication

The 151 peer reviewed articles included in the synthesis were published in 95 different academic journals. The journals appearing most frequently were the *International Journal of Sustainability in Higher Education* ($n=18$), *Journal of Cleaner Production* ($n=12$), and *Sustainability* ($n=10$). Many of the included journals only had a single article which met the criteria for inclusion ($n=78$), thus demonstrating the wide range of relevant academic disciplines beyond the field of education, and subfields within education, in which links to the role of the university are made. Some were published in journals with specific climate sub-thematic foci, such as Energy Policy or Coastal Management, which made connections with the education field. Others were in education journals with a sub-thematic focus such as the *Journal of Chemical Education* or the *Journal of Science Teacher Education*, making connections with the climate crisis. A final set were published in journals with general thematic relevance such as the *Journal of Global Environmental Politics* or *Policy Sciences*, cutting across climate and higher education. Table three (below) gives an overview of journals with two or more included articles to signal the most well-represented journals. A table with the full list of included journal articles and numbers of articles included from each is included in the appendices (appendix 3).

One finding related to publication is particularly worth noting: none⁹ of the articles reviewed were published in well-known higher education studies or comparative and international education journals (despite the presence of these journals in the Web of Science database). We see this as an important concern for both the higher education field, and the comparative and international education fields more broadly.

Table 3. Journal of publication

Journal of publication	Number of studies
International Journal of Sustainability in Higher Education	18
Journal of Cleaner Production	12
Sustainability	10
Climatic Change	4
Journal of Chemical Education	3
Local Environment	3
Australian Journal of Environmental Education	2
Bulletin of the American Meteorological Society	2
Ecology and Evolution	2
HortTechnology	2
International Journal of Climate Change Strategies and Management	2
International Journal of Global Warming	2
Journal of Contemporary Water Research & Education	2
Journal of Environmental Psychology	2
Journal of Extension	2
Law and Policy	2
Nurse Education Today	2
Weather, Climate, and Society	2

5.3 Geographical focus

The table below represents the geographical spread of articles and number of articles from each country which have been included in the syntheses of this review, categorised by 28 individual 'countries of focus', i.e., where the research took place. There were some instances where research was published by authors in a context other than that where the research took place, particularly across partnerships – where this is the case we have noted in the synthesis.

The geographical phase of the mapping revealed the concentration of literature in countries from the Anglophone Global North, with the highest number of articles coming from the USA ($n=51$), Australia ($n=16$), Canada ($n=12$), and UK ($n=10$) respectively. These countries correlate with those that are both defined as high-income and scoring highly on development indices, as well as countries that are both historically and contemporarily responsible for high levels of emissions (Oxfam 2020). Our findings here also echo those of other studies which highlight global inequities in publication rates (both in academic publishing in general, and climate and education publishing in particular), including one article synthesised as part of this review (Czerniewicz, Goodier, and Morrell 2017). We recognise that our methodological choices around language and choice of database will have impacted these findings around geographical spread, and it is important to interpret these findings with this in mind.

⁹ International Journal of Sustainability in Higher Education has not been included in this category as although it contains the term 'higher education' in its title, it is focused more on sustainability, environmental action and associated areas than on higher education studies, in terms of its authors and editorial board.

Table 4. Country focus of study (single context)

Country	Number of studies
USA	51
Australia	16
Canada	12
UK	10
Germany	4
Spain	4
South Africa	3
Malaysia	2
Serbia	2
Turkey	2
Botswana	1
Brazil	1
Chile	1
China	1
Costa Rica	1
Ethiopia	1
Finland	1
France	1
Italy	1
Japan	1
Mexico	1
New Zealand	1
Nigeria	1
Philippines	1
Portugal	1
Saudi Arabia	1
Seychelles	1
Switzerland	1

We also grouped the single country context studies by geographical regions, again following the World Bank's regional divisions. This regional mapping further highlights the dominance of studies from the Anglophone Global North, particularly North America (i.e., the USA and Canada). Within other regions, articles emerging from the East Asia and Pacific region were dominated by Australia (n=16). In the Europe and Central Asia region, studies focused on the UK surpassed those from other European countries (n=10). Some articles were included from Sub-Saharan Africa (n=7) and Latin America and the Caribbean (n=4), but only one article from the Middle East and North Africa and no articles from South Asia were included.

Table 5. Regional focus of single country studies

World Region	Number of studies
North America	63
Europe and Central Asia	27
East Asia and Pacific	22
Sub-Saharan Africa	7
Latin America and Caribbean	4
Middle East and North Africa	1
South Asia	0
Total	124

In addition to the 124 single-country focus studies, there were 27 articles which offered multi-country analyses of university responses to the climate crisis. These articles broadly followed the pattern of single-country studies discussed above, i.e., they also tended to focus on countries from the Anglophone Global North, comparing, for example, US and Canadian universities (n=3). The USA dominated too in terms of its involvement in studies with other countries (n=3), two of which were collaborations with Europe. Two of the multi-country articles further compared universities within the European Union. There were some North-South collaborations (n=4), but very few South-South collaborations represented in these studies (n=2). Some international collaborations (n=3) involved cross-country surveys of 25 countries or more, and did not specify their geographical context.

Table 6. Country focus of study (multi-context)

Countries	Number of studies
International (unspecified)	3
International (Europe and Central Asia)	3
Canada, USA	3
Australia, New Zealand	1
Belgium, Germany, Netherlands, Portugal, Spain, UK	1
Bolivia, Paraguay, Uruguay, Venezuela	1
Brazil, China, Germany, Mexico, Saudi Arabia, USA	1
Brazil, China, India, Mexico, Russia	1
Canada, Caribbean	1
Canada, Finland	1
China, UK	1
Colombia, Ecuador, Mexico, Peru, Spain	1
Finland, Kenya	1
Germany, Portugal	1
Germany, Spain, UK	1
Germany, Uganda	1
Germany, USA	1
Italy, USA	1
International (East Asia and Pacific and North America)	1
International (North America and Sub-Saharan Africa)	1
International (North America, Europe and Central Asia)	1
Total	27

The salient interpretative point associated with this mapping is thus not that we believe that climate-related initiatives are concentrated in the Anglophone Global North. Rather, this global mapping highlights that work on climate may be dislocated from universities in the global majority, and/or that this work is not being published in English in the Web of Science database. Their omission also reflects the elite orientation of Web of Science more generally, potentially reflecting uneven research environments in terms of funding, research priorities, type of publication and work happening outside of the more elite academic publication pipelines.



Other more specific absences were also revealed through this process: of the emerging economies dubbed the 'BRICS' (Brazil, Russia, India, China and South Africa), only one of the 151 articles synthesised for this review included Russia or India, and this was a multi-country study that did not focus on either country in detail. Brazil and China were represented by one single country study each, with three studies in the South African context. There were only two articles emerging from OPEC states: one focused on Nigeria, and one on Saudi Arabia. Two additional articles included Saudi Arabia and Venezuela in their multi-country contexts. Finally, there was only one article published on a small island developing state (the Seychelles). Given the huge range of work associated with education and climate in these contexts, it is noteworthy that this work may be disconnected from higher education institutions and systems, or may be part of the everyday experience of HEIs in these contexts but not the topic of publications in the Web of Science database by actors within (or outside) HEIs in these contexts.

5.4 Methodology of study

For articles to be included in this review, they needed to explicitly discuss their methodology, although this did not necessarily need to be in a separate 'methodology' section. Rather than deciding as a review team how to categorise studies by methods, we have categorised studies according to how the authors of each included article represented their own work. The table below shows the different types of study included in this review: qualitative studies made up approximately half of the included studies, the same number as quantitative and mixed methods studies combined.

Table 7. Methodology of study

Type of Study	Number of studies
Qualitative	74
Quantitative	30
Mixed methods	47
Total	151

Reflecting on the methodological approach also generated some important questions in relation to types of evidence. We were interested to explore not only about whether studies were quantitative or qualitative in nature, but also their sampling strategies, the scale and/or scope of studies, and the kinds of metrics used to evidence impact and outcomes of university responses to the crisis. This discussion has been integrated into the thematic synthesis which is the following part of the report (part six of this report), as well as underpinning the typology of change.

As tables seven and eight (below) highlight, there was significant variation in the different types of both qualitative and quantitative methods deployed by the studies, which we have grouped into broad categories. We have not provided totals for these tables, as many studies deployed more than one of these methods; rather the

aim is to show which methods are most commonly used, and so the tables are ordered by frequency.

Under qualitative methods, 'information consultations and reflections' included diverse informal methods such as post-workshop evaluations, evaluations with staff and/or students, or written reflection from the implementer of an intervention. Interestingly, these written reflections often proposed (but did not implement) more formal frameworks for analysis. Our category of 'documentary analysis' included various written documents, whether published on paper or online, including policies, university sustainability reports, or newspaper articles, while we grouped together interviews and focus groups as different kinds of dialogue. Under 'participatory methods', we included methods such as games involving marketing experiments or participatory budgeting. 'Participant-observations' were defined differently by different authors, some as non-neutral activist participation, others as passive, silent observers. Finally, one article involved digital story-telling.

Table 8. Qualitative methods

Qualitative Methods	Number of studies
Informal consultations & reflection	39
Documentary analysis	38
Interviews and/or focus groups	35
Qualitative analysis of survey data	28
Participant-observations	12
Participatory methods	11

Under quantitative methods, most studies involved quantitative analysis of survey data, which included surveys of various populations, most commonly of students of a particular course, but also including the general public or external community stakeholders. A sub-set of these surveys which we have separated out were pre- and post- questionnaires, which were almost exclusively found in the education modality of the university as a measurement of changes to student knowledge or attitudes. 'Environmental gauges' we defined as those which presented direct quantitative indicators of climate change, such as emissions, but also included articles measuring ecological footprints, ice coverage or water flow. A final two articles created numerical ratings or indices, to measure climate policies or divestment decisions.

Table 9. Quantitative methods

Quantitative Methods	Number of studies
Quantitative analysis of survey data	62
Pre- and post- questionnaire	13
Environmental gauges	9
GIS/GPS mapping/modelling	3
Rating & indexing	2

5.5 Thematic Mapping

The table below highlights the dominant theme, as defined by the authorial team, of each of the articles which have been included in the synthesis which follows. In cases where this dominant or over-arching theme was hard to identify, for example in articles which addressed both curriculum and pedagogy, or in articles that explored community engagement with pedagogical implications, these were discussed in a meeting by the review team.

We sub-divided the three themes which included more than thirty studies in the following ways:

- i. Education
 - a) Curriculum
 - b) Pedagogy
 - c) Teacher education
- ii. Knowledge production
- iii. Community engagement
 - a) Partnerships within education systems
 - b) Partnerships beyond education systems
- iv. Public debate
- v. Campus operations
 - a) Greening the campus
 - b) Governance

Where these divisions are made, we nevertheless signal linkages and connections between them in the synthesis. A more nuanced version of Table 10 (below) is provided in Appendix 5, indicating the overlaps and synergies between different themes.

At times, the coding of articles into different university modalities led to some outcomes of note: in particular, there are a few instances in which similar articles by overlapping authors are synthesised in different themes. One article on integrating curricula, research and extension activities, for example, is synthesised in the curriculum sub-theme of education (Monroe, Ireland, and Martin 2015), while a second is synthesised in the community engagement modality (Monroe and Oxarart 2019). Equally, one article focused on the pedagogical value of community partnerships and ‘real life’ applications of climate science is synthesised in the pedagogy sub-theme of this review (Booth, Aben, et al. 2020), while a second is synthesised in the community engagement modality (Booth, Earley, et al. 2020). These articles highlight the inter-connectedness of the modalities: our argument is that each of these modalities should not be considered as stand-alone, rather that the boundaries between them are porous. Considering the same project from different angles can lead to usefully varied forms of analysis. These inter-connections are also relevant to understanding the community engagement modality more broadly, which was both the most diffuse in terms of content, and simultaneously the modality with the strongest connections with other functions of the university. As a modality inherently concerned with partnerships, this is not surprising.

Table 10. Thematic mapping (by university modality)

University Modality	Number of studies
Education	65
Knowledge production	3
Community engagement	36
Public debate	10
Campus operations	37
Total	151

This table is thus only indicative of the themes which we aim to cover in nuanced and in-depth ways in the synthesis which follows. It reveals a reasonably diverse set of ‘responses’ to climate change, across the five dimensions of the university in the framework which we engage with. The smallest number of articles are synthesised in the knowledge production function of the university, which is concerned with knowledge generation and innovation. This may be a function of our methodological choices – we did not search for ‘research’ as a separate research term in the way that we did for ‘campus’, because ‘research’ is far too general a term used in abstracts and would have led to a large number of articles which did not in reality meet our search criteria. It is very important to note that we are not suggesting that universities are not working on and publishing excellent climate science – the IPCC reports are evidence of this. We do think, however, that the smaller number of articles included in this modality indicates as a relative paucity of published meta-reflection on the implications for institutions of processes of research, and the dynamics of power and funding, for example, behind this research. In addition to these three, we found a further 11 articles concerned less with the generation of knowledge but more with its dissemination. Research dissemination clearly connects knowledge production with public debate and community engagement; we chose to synthesise these 11 articles within the community engagement function because they focused on questions of stakeholders in the process of communicating research.

Finally, the relatively small numbers of articles synthesised in the public debate function of the university – i.e., which focused on this topic, rather than signalling public debate briefly in their work – might also be expected. We also did not search for articles which included ‘public debate’ as a specific term in their abstracts. But it is important to consider whether this relative paucity of articles reflects that this function of the university is often overlooked, or not considered in depth in published work.

The mapping strategies included here were not the only categories which we brought to bear in understanding the different university responses to climate change, but they are the five which we consider the clearest and most useful way of dividing up the studies. In the synthesis which follows, other reflections are also included. For example, where studies have been explicit about their conceptualisation of climate change, this has been included in the synthesis, and, where relevant, discussions of whether particular types of response correlate with mitigation, adaptation or climate



justice strategies have been included. There is also, of course, a use in combining these different mappings: in the synthesis which follows connections between geographies and types of university response to the crisis, or types of methodology and type of university of response, also form part of the reflections.

5.6 Generating a typology of change

A final type of mapping related to the type of evidence which the articles provided. After the first draft of synthesis, the authorial team came together to discuss ways in which we could explore the types of evidence of effective university responses to the climate crisis which this systematic review has generated.

Four related sub-questions emerged related to evidence:

What types of change are discussed in studies providing evidence of impact?

Where, and in whom, are these changes located?

How are these changes being measured?

Which types of change predominate in each university modality?

From this discussion, three related types of empirical data began to emerge that are represented in this review, which we draw on to generate the typology that forms the basis of part seven of this report. These three types of study are as follows:

i. Articles that **surveyed the field** – i.e., identified practice through a university response to the climate crisis that was in place such as a curriculum intervention or institutional policy, but did not provide evidence of a relationship with perceived (type 2) or actual (type 3) impact of this university response. These articles were concentrated in the curriculum sub-theme of the education modality (n=10) and the governance sub-theme of the campus operations modality (n=3). They tended to draw on either documentary analysis (for example of curricular content or policy documents) or qualitative research such as interviews with academics about the content of these documents. Often, these articles held underlying assumptions about the impact of either policies or curricula – i.e., that having them in place would lead to positive outcomes – but they did not provide evidence to support these underlying assumptions.

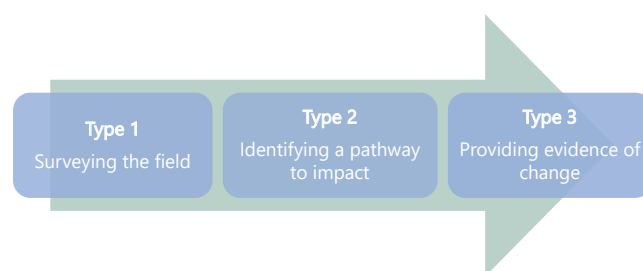
ii. Articles that **identified a pathway to impact** – i.e., argued for or theorised the effectiveness of a particular process or university response to the crisis, but without evaluation of the outcomes. These articles tended to offer normative and/or theoretical perspectives, although they always drew on evidence to do so (and thus met our empirical criterion for inclusion). Large scale surveys often fell into this category, for example an article in the knowledge production modality which asked academics their perspectives on potential barriers to successful implementation of research (Leal Filho et al. 2018), or an article which drew on international research

to generate a conceptual framework for effective climate change education (Molthan-Hill et al. 2019). Other articles persuasively used data to illustrate but not evaluate their argument, for example, an article in the community engagement modality which highlighted the importance of the inclusion of indigenous community stakeholders for work on climate in the arctic (Tremblay et al. 2008).

iii. Articles that **provided evidence of change** – i.e., by empirically evaluating a pathway to impact, and explicitly measuring a type of change associated with a university response to the climate crisis. Both these changes and the kinds of associated measurements were diverse (and discussed in detail in part seven of this report), but included, for example, measurements of change such as quantitative assessments of emissions reductions, or measurements of behavioural or attitudinal change (e.g. of students before and after a curricular intervention, measured by surveys). Where articles included this analysis of the effectiveness of a pathway to impact, they were explored in more depth and were seen as the strongest form of evidence of the potential impact of universities on the climate emergency. Each of these articles contribute to the typology of change which concludes this report. A summary table of these articles is provided in appendix four of this report.

We have chosen to conceptualise these different types of types of articles on an arrow, to suggest the ways in which type three is on a continuum with the first two types of articles (to different degrees in different articles). For articles exploring pathways to impact and/or providing evidence of change, however, the mechanisms by which the field was surveyed varied, i.e., these articles did not always offer a comprehensive empirical analysis of the state of the field before theorising pathways to impact. In many of the articles defined as type two and type three, the surveying of the field happened through literature review, rather than through direct empirical exploration.

Figure 3. Mapping evidence of change



It is important to note explicitly that what we are not suggesting by this arrow is a hierarchy: we do not think that the type three empirical articles providing evidence of change are necessarily more important or of higher quality than articles at the first or second stages of the continuum. What we do want to argue, however, is that articles defined as type three are doing something different, and that offering evidence of a pathway to impact may be something that other academics working in these fields may like to consider, particularly if their work draws on an underlying assumption, for example, that increased student knowledge will always lead to positive climate

outcomes or actions (which our research, as others, shows not to always be the case). We also, through this arrow, want to suggest that ‘what works’ discourses rely heavily on ‘what matters’ discourses in this field: providing evidence of change should, ideally, constitute a reflection on what knowledge exists thus far, a theory of change and a measurement of change, i.e., a combination of theorisation and evidence. As our conclusion will argue, however, these theories of change tended not to be further embedded in theories of justice: only one article in the review referred to ‘climate change’ as a question of justice. Problematising the ways in which evidence of change might contribute to technicist understandings of the crisis is also an important reflection arising from this review.

The following table provides a headline summary of the number of articles in each modality which we have defined as each of the three types. In the final column, we have included this count as a proportion of the total number of articles in each modality. As is clear from the table, half of the articles included in this review provided evidence of change (76 of 151 articles in total). Our methodological choices will of course have impacted on this proportion, given our explicit interest in empirical research, and our exclusion of articles which were solely theoretical or normative during the screening process.

It is also important to note, when looking at this table, that measuring change may be easier or more common in some university modalities than others. For example, it is common to conduct evaluations after courses have been delivered, measuring changes to students’ self-reported knowledge. It is much less common, and indeed much harder, to measure the impact of research, as is reflected in the absence of ‘type 3’ articles in the knowledge production function of the university. Equally, within the campus operations function of the university, only one article measured the impact of institutional policies or statements, which may be equally diffuse and hard to measure. What we do want to suggest, however, is that this gap in our understanding of ‘what works’ is important, both for contributing to understandings of the specific outcomes and impact of different modalities of the university, but also to support the case that universities are important actors in contributing to responses to the climate crisis.

Table 11. Number of studies surveying the field, identifying pathways to impact or providing evidence of change

University Modality	Surveying the field	Pathways to impact	Evidence of change	Evidence of change (%)
Education	10	8	47	72% (65 studies)
Knowledge production	-	3	-	0% (3 studies)
Community engagement	-	23	13	36% (36 studies)
Public debate	-	2	8	80% (10 studies)
Campus operations	3	26	8	22% (37 studies)
	13	62	76	50% (151 studies)

Where articles did provide evidence of change, this is signalled in the text of the synthesis which follows. This collective analysis around evidence of change was further used to generate a table for collective discussion between authors about types of change, whether in terms of knowledge, attitudes, behaviours, institutional changes to governance or teaching (e.g., to curricula, pedagogy, or policies), changes to physical infrastructure (e.g., modification of buildings), or, finally, measurement of atmospheric changes in emissions reductions. This table of documented changes in each of the modalities is provided in appendix four. Part seven of this report fleshes out this analysis in detail, offering a typology of change for the kinds of evidence of effective university responses to the climate crisis articulated in the 151 articles included in this systematic review. This typology aims to contribute to how we might understand holistically what a university which responds to the climate crisis might look like, and how some of these responses might be measured.

6.0 Synthesis: University responses to climate change

This chapter synthesises the substantive findings of the 151 empirical studies included in this systematic review, in order to generate a global picture from the kinds of work universities are doing in different contexts across five different modalities of the university: education, knowledge production, community engagement, public debate and campus operations. The three modalities with the highest numbers of synthesised articles – education, community engagement and campus operations – have been further sub-divided for ease of reference. The first of these, education, covers three broad areas – curriculum, pedagogy and teacher education, as well as signalling inter-linkages. The campus operations function of the university was also sub-divided into broad themes: ‘greening the campus’, which focuses on aspects of physical infrastructure; and ‘governance’, which focuses on policy and institutional commitments to respond to the climate crisis. Finally, the community engagement section considers sites of connection within education systems (i.e., between different universities, or between universities and schools) and with external stakeholders (who are diversely represented in this review, including community stakeholders, the general public, the business community, policymakers and so forth).

6.1 Education

This modality or dimension is one of the most recognisable ‘pillars’ of the university and refers to the university as a space for learning, and for personal, civic and professional development (McCowan 2020, 7). It is the most prominent function of the university, and many HEIs only have this function; it was unsurprisingly the biggest modality, with 65 included articles in total. Under this theme, 30 articles focused on curricular interventions in relation to the climate crisis, 31 focused more on pedagogy, and a final sub-set of 4 articles focused on teacher education, predominantly for future work in primary and secondary schooling.



6.1.1 Curriculum

We have synthesised articles under 'curriculum' where this is their focus, signalling links with the pedagogy theme (part 6.1.2, below) in the text. A total of 30 articles were synthesised under this sub-theme, collating articles which were focused on the content or assessment of subjects or courses. In this sense, these articles focused on the official curriculum, and tended not to focus on the unofficial curriculum, or what might get taught in practice.

Following the pattern identified in our geographical mapping of articles, the largest proportion of the articles in the curriculum sub-theme were published by authors in the Anglophone Global North, with ten articles published by authors in the USA, and four from Australia. Four further articles were published focused on European settings, with one article each from Germany, Portugal, Serbia and Spain. There was one study in the context of a small island developing state, namely Seychelles (Krütli, Pohl, and Stauffacher 2018), while a second reported on research conducted in the context of island nations, focused on the Philippines (Coronacion 2015). One article focused on an OPEC member: Saudi Arabia (Cruz, Alshammari, and Felicilda-Reynaldo 2018), and a final article on Chilean research (Rojas et al. 2017).

In addition to these articles with single-country foci, there were seven articles with multi-country contexts. Of the seven multi-country research articles, one study had respondents from 45 countries (Molthan-Hill et al. 2019), one study involved the BRIC countries along with Mexico (Ferreira et al. 2012), and one involved a collaboration between researchers from a European (Finland) and an African country (Kenya) (Arevalo, Pitkänen, and Kirongo 2014). Three articles of 30 thus involved an inter-university Global South-North collaboration (Ferreira et al. 2012; Arevalo, Pitkänen, and Kirongo 2014; Krütli, Pohl, and Stauffacher 2018); the remaining multi-country articles reported on research in the Global North, such as a survey with respondents in the UK, Spain and Germany. These articles deployed a variety of methods to explore curricular interventions, with a balance of 12 articles using mixed methods, 10 using qualitative, and eight using quantitative methods (all of which were surveys with two additionally administering pre- and post- questionnaires).

The articles also could be also categorised in terms of the focus of the curricula under analysis. A total of five articles focused on modules that considered climate change as a specific focus, whether in terms of mitigation, adaptation, or climate communication, while an additional two articles considered the extent to which climate change was integrated into higher education curricula in general. Three further articles looked at the broad discipline of sustainable development, but with specific reference to the climate crisis.

A range of articles considered the topic from single-discipline perspectives. Four articles considered curricula in physical and mathematical disciplines: biology, chemistry, maths, and renewable energy. One article considered the overall geography curriculum, while another four considered specific aspects of the physical environment and climate change, with two articles looking at

forestry curricula, one on agriculture and one on horticulture. There were a further two articles where the curricular context was architecture and the built environment. Five articles considered the topic of climate change from disciplines associated with health, including three articles on nursing, one on social work, and one on psychology. Finally, two articles focused on curricula which approached the climate crisis from either a legal or historical perspective, while a third was interested in the business studies curriculum. There was thus a relative preponderance of STEM and related disciplines in curricular response to climate change as compared to social sciences and humanities, pointing to a particular kind of treatment of climate change in university curricula. This helps in locating climate change in the knowledge-scape of universities, constructing it as a technical rather than socio-political concern, but also signalling the range of diverse disciplines in which the climate crisis has been represented.

In addition to the articles which focused on a single discipline, there were two which were inter- or multi- disciplinary in nature. The first of these discussed a case at a university involving multiple curricular (and pedagogical) approaches to climate-related health effects, which drew from disciplines of medicine, public health, law (environmental), and nature conservation (Lavey 2019). The second discussed the case of a transdisciplinary approach to establishing a sustainability learning laboratory in a real-world context (Krütli, Pohl, Stauffacher, 2018). The students participating in this lab had diverse disciplinary backgrounds and foci such as environmental science, engineering, agriculture, and planning sciences.

Of these 30 articles which focused on curricular responses within universities, 10 were characterised by work surveying the field: eight by investigating university curricula using document analysis, surveys and/or interviews to evaluate the ways and extent to which climate change and related issues were embedded in them (Álvarez-Nieto et al. 2018; Coronacion 2015; Hess and Collins 2018; Lohr 2014; Molthan-Hill et al. 2019; Pearson 2013; Pease, Chaney, and Hoover 2019; Thomas, Jennings, and Lloyd 2008). While these analyses offered empirical evaluations, they did not involve conducting an active intervention such as revising the curriculum or attempting to theorise or empirically evaluate any change in students' state of understanding or their beliefs and attitudes. A further two of these ten studies did assess some aspects of students' cognitive and affective domains, such as their awareness, knowledge, skills, attitudes and/or beliefs about issues related to climate change, but were not assessing change within these domains (Cruz, Alshammari, and Felicilda-Reynaldo 2018; Rojas et al. 2017). Interestingly, three of these ten studies analysing the state of the field involved cross-border contexts, looking at Australia and New Zealand (Thomas, Jennings, and Lloyd 2008), three European countries (Álvarez-Nieto et al. 2018), or survey data from 45 countries from Africa, Asia, Europe, North America, Oceania, and South America (Molthan-Hill et al. 2019).

A second sub-set of 20 articles reported on research that involved bringing some form of change, for instance, revising an existing curriculum or creating a new one. Three of these studies explored revision or modification of curricula, although without offering

assessment of effectiveness of the change (Fahey 2012; Boddy, Macfarlane, and Greenslade 2018; Arevalo, Pitkänen, and Kirongo 2014). The study by Arevalo, Pitkänen and Kirongo (2014), a Kenyan-Finnish collaboration, explored and revised the forestry degree curriculum at a Kenyan university for its coverage of climate change. Two methods were employed to conduct the curriculum review - (i) a SWOT analysis of the existing curriculum, and (ii) a survey of 45 stakeholders consisting of representatives of Ministry of Forestry and Wildlife, the Kenyan Forest Service, students, private sector organizations, and other employers in which they assessed the importance and coverage of a range of competencies in the existing curriculum. The study by Fahey (2012), describing the reformation of an existing master's degree curriculum in climate change adaptation in Australia, accounted changes in the curricular design without going into the empirical evaluation of those changes. The article described how two models for curriculum design, viz. outcome-led model and process-inquiry based model, were incorporated into the revised curriculum. In the article by Boddy, Macfarlane and Greenslade (2018), with a disciplinary focus on social work, the researchers discussed the embedment of topics related to natural environment into existing units of online master's degree courses at two Australian universities. It acted as a demonstration of how the environmental topics could be included in the existing curricula. However, the effect on students of this curricular change, or the efficacy of the inclusion of the environmental content as a response to the climate crisis, was not measured.

One article, while not measuring change, proposed a theoretical framework to analyse the embedment of climate change in higher education, drawing on an international survey (Molthan-Hill et al. 2019). The following discussion will draw on elements of that paper by looking at various aspects of research articles such as nature of collaborations, focus of generated evidence, i.e., what the evidence is for, the discussion of findings, researchers' reflections, and the recommendations.

We sub-divided the 17 articles which provide evidence of the effectiveness of curricular interventions into six themes:

- i. impact on student knowledge (four articles);
- ii. impact on students' attitudes and beliefs (four articles);
- iii. impact on students' behaviour (three articles);
- iv. discussion of Massive Open Online Courses (MOOCs) (two articles);
- v. North-South collaborations (two articles); and,
- vi. the role of climate change as rich context for the curriculum (four articles).

There were four articles (Lavey 2019; Stupar, Mihajlov, and Simic 2017; Smith, Banet, and Martinez Romera 2019; Wasco 2019) which measured the change in student knowledge about climate change and related issues. Three of them used the case study approach (Lavey 2019; Smith, Banet, and Martinez Romera 2019; Wasco 2019), while the remaining study (Stupar, Mihajlov, and Simic 2017) used pre- and post-questionnaire (n = 246). Lavey (2019) evaluated a programme focusing on climate related health effects (CRHE) at

a US university. They found enhancement in students' learning about CRHE based on analysis of students' engagement with the activities or assignments of the programme. Conducting a multi-country study (US, Denmark, and Norway) of an international undergraduate legal course on law of energy transition, Smith, Banet, and Martinez Romera (2019) measured the effectiveness of the programme through student feedback which largely focused on benefits owing to the cross-contextual, collaborative nature of the programme. Noteworthy was the evidence of knowledge production in the form of a paper written by a group of students which was slated to be published in a peer-reviewed journal. Stupar, Mihajlov, and Simic (2017) evaluated the impact of a Serbian undergraduate architecture course on climate change mitigation and adaptation in urban settings, and found improvement in students' awareness and knowledge about climate change. Wasco (2019) evaluated, through student feedback, an US online nursing course focusing on impact of climate change on human health. However, the article did not mention how the feedback was collected, and from how many students. The article shared some selected feedback comments from the students which indicated an increased awareness of health-related effects of climate change.

Three articles discussed the effectiveness of curricular interventions with reference to impact on student behaviour (Nam and Ito 2011; Cordero, Centeno, and Todd 2020; Hay and Eagle 2020), all based in institutions in either the USA (n=2) or Australia (n=1). Cordero, Centeno and Todd (2020) evaluated the impact of a course in climate change at a US university on the students' long-term personal carbon footprint, through a survey of students (n=104) at least 5 years after taking the course. The article noted that the participants indicated a personal connection with climate change, and their personal agency was manifest in their personal actions or their perceived confidence in their ability to take action. Also drawing on a student survey (n= 380), Hay and Eagle (2020) aimed to determine whether, and in what ways, the attitudes, beliefs and perceptions of undergraduate business students at an Australian regional university concerning climate change appeared to have changed. This was done by comparing the findings from a survey of the cohort at two time points in time: 247 students in 2012 prior to the change in curriculum, and 133 students in 2015 after the change in curriculum. They found there was increased awareness of climate change, enhanced understanding of contributors to climate change, and enhanced sense of collective social and governmental responsibility to mitigate climate change. A third study by Nam and Ito (2011) is in a sense antithetical to the previous two, because it offered evidence of little or no impact on change in students' environmental behaviour. They evaluated the impact of an undergraduate course on human history and climate change at a US university through mixed methods consisting of content knowledge questionnaire, classroom observation, interviews, and survey. Evidence was obtained focusing on enhancement of students' understanding, skills and attitudes about historic interactions between human society and climate, and improvement in literacy competencies related to science of climate change. However, evidence also showed little or no impact on change in students' environmental behaviour. Two of these articles which looked at student behaviour also included some assessment of impact on students' attitudes and beliefs about issues related to



climate change (Nam and Ito 2011; Hay and Eagle 2020).

A further four articles generated evidence of change in students' attitudes and beliefs about issues related to climate change, but without looking at behaviour (Cantalapiedra, Bosch, and Lopez 2006; Duffy, Hammond, and Cheng 2019; Ferreira et al. 2012; Hanrahan and Shafer 2019). These four studies all employed surveys to generate evidence of impact. They looked at a range of dimensions of student attitudes and beliefs such as their sensitivity towards environmental issues (Cantalapiedra, Bosch, and Lopez 2006), belief in efficacy of taking action, whether individually or collectively (Ferreira et al. 2012; Duffy, Hammond, and Cheng 2019), sense of responsibility for engaging in public outreach activities, and interest in exploring career paths related to climate change (Hanrahan and Shafer 2019). The study by Duffy, Hammond and Cheng (2019) is notable for one particularly interesting finding. The study aimed to understand the change in students' beliefs, sentiments and understanding about climate change through taking an introductory biology course. The study provided evidence for pessimism among students about humanity's intervention to tackle the global crisis despite, or in some sense because of, an enhanced understanding of the issue. Consequently, the authors advocate a "writerly" climate change literacy, meaning developing an action-oriented stance through which students would process and act on their "readerly" climate change literacy, i.e., what they learnt about climate change, to foster among students a critically informed sense of empowerment and hope for taking action.

Two of the 17 studies which provided evidence of change through curricular interventions looked at the impact of MOOCs on climate change (Coelho et al. 2015; Otto et al. 2019), a form of pedagogy that will be discussed in more detail in the pedagogy synthesis below. Coelho et al. (2015) assessed active participation and the impact of a pilot MOOC developed and run by a Portuguese university. They used a case study approach and generated data from 1024 students based on their engagement with digital platforms in terms of number of users, page-views, and posted messages. While the article claimed an enhancement in students' knowledge and awareness regarding climate change, it should be noted that the only evidence offered in the article is in the form of completion rate for the MOOC. Otto et al. (2019) evaluated the impact on learning for two climate change MOOCs conducted by two German and Portuguese universities. They generated evidence using a post-questionnaire. The evidence focused on students' self-perception of improvement in their knowledge and competencies related to climate change. Importantly, the student self-assessment showed that they perceived an enhancement in their understanding of the link between climate change and social justice, and they also perceived an improvement in their competency of communicating the aforementioned link to others. This was the only study of the 34 which talked about evidence of effectiveness of curricular intervention in terms of social justice. The article framed the design of MOOCs with a clear and dedicated focus on critical exploration of climate change. This was evident in the aims of the MOOCs which were to enhance the participants' ability to engage critically in debates around climate change and climate justice, while looking at an impending international climate conference as the opportunity

for the participants to engage with the conference proceedings and debates surrounding it.

A further two articles provided evidence of impact in the context of Global South-North collaboration. The research by Krütli, Pohl and Stauffacher (2018) involved a collaboration between University of Seychelles, Ministry of Environment, Energy and Climate Change of Seychelles, and ETH Zurich. Their article described and analysed an integrated, transdisciplinary teaching-research activity, known as 'real world laboratory', on sustainability in a SIDS country, viz. Seychelles. This was a prototype of a sustainability learning lab (SLL). Although the recognition of high vulnerability of SIDS to climate change was one of the key factors in locating the lab in Seychelles, the findings in the article did not point to impact specific to climate change. Using a case study approach the article offered evidence on improvement in students' learning of general scientific skills and competencies. In the second of these articles discussing South-North collaborations, Ferreira et al. (2012) described and evaluated an international online course run by a consortium of HEIs from multiple countries from Global North and South, specifically the USA, Brazil, Russia, India, China, and Mexico. Through pre- and post-questionnaires administered to 43 students, evidence was obtained for increased awareness about global warming, improved self-efficacy belief about personal action for mitigating climate change, and better understanding of governmental policies on climate change for countries represented in the student cohort. It should also be noted, however, that while these two articles (Ferreira et al. 2012; Krütli, Pohl, and Stauffacher 2018) represented a Global South-North inter-university collaborative effort, the recognition as knowledge producers, in the form of authorship of the studies, was confined to affiliates of universities in the Global North.

There were three studies (Burandt and Barth 2010; Monroe, Ireland, and Martin 2015; Mahaffy et al. 2017), which embedded climate change instrumentally in the curriculum. The noteworthy feature of these studies was that the issue of climate change appeared secondary, supplementary rather than constitutive, to pedagogical concerns such as enhancing students' generic scientific skills and competencies. For example in Mahaffy et al. (2017), climate change, as "one of the defining sustainability challenges of our century" was selected "as a rich context" to introduce topics such as isotopes and gases into undergraduate general chemistry courses (Mahaffy et al. 2017, 1027). These three studies focused on development of competencies related to collaboration, interdisciplinary work on complex, real-life world problems, and self-directed learning (Burandt and Barth 2010), significance of students' engagement with complex systems for authentic science learning (Mahaffy et al. 2017), and different elements of the course such as interdisciplinary research, online and distance learning, and connection between research and extension (Monroe, Ireland, and Martin 2015).

In summary, these 17 articles provide a window into the range of ways in which universities have engaged with climate change in the curricular domain. Researchers took diverse approaches and employed a range of research methods, with varying degrees of rigour underpinning the findings. Moreover, the six themes also foreground that the university curricular response to climate

change can be understood not only in terms of impact on students (their knowledge, awareness, attitudes, beliefs, and behaviour), but also in terms of use of non-conventional platforms such as MOOCs for design and implementation of curricula on climate change, the nuances of the role of climate change in curriculum, and in terms of “who is asking the questions”, i.e., the nature of researcher collaborations.

This synthesis could potentially inform the development of evaluative framework(s) for processes of knowledge production and validation in relation to evidence of the importance of curricular developments responding to the climate crisis, but an important note is needed about the underlying assumptions that may have been present in these articles. The review found that one-third of all the articles on curriculum (10 of 30) surveyed the field, for instance, the extent of integration of climate change in curriculum. However, these articles did not provide evidence of further consequences or follow-ups, for instance, a revision of curriculum, or indeed a measurement of changes in students’ knowledge, attitudes, or behaviours (which may have to do the point in time at which these articles were published). Our argument is thus that while curricula can be assumed to contribute to the climate crisis, more extensive and better directed research is needed. The other dimension to curricular interventions is of course the ways in which they are enacted within pedagogical encounters. The following section considers these forms of pedagogy in detail.

6.1.2 Pedagogy

A total of 31 studies were synthesised under the theme of ‘pedagogy’ as a form of university response to the climate crisis. For the purposes of this review, ‘pedagogy’ may best be understood as encompassing both practical instances of and theoretical approaches to teaching and learning about issues pertinent to climate change and sustainability. The majority of these studies (n=20) were based in the Anglophone Global North: the USA (8), UK (4), Australia (5) and Canada (3). An additional three were based in Europe, with one study each in Finland, Germany and Serbia. Only two were based in contexts in the Global South, with one study each in Brazil and Malaysia. The remaining six were multi-country studies.

The 31 articles discussed under ‘pedagogy’ are framed through a variety of sub-themes. A total of ten articles drew on topics of incorporating holistic, interdisciplinary approaches to sustainability education and distributing leadership as a result of pedagogical interactions. A further 14 articles focused heavily on real-world application of concepts, action or immersive learning experiences, and involvement with the local environment or community. Seven articles discussed the use of online learning platforms and new technologies for the teaching and learning of climate change and sustainability education. Finally, four articles identified degrees of student unpreparedness and areas of improvement pertaining to existing educational or training programmes. As four articles bear importance to more than one sub-theme and are addressed accordingly as they relate to different topics, the total number of articles represented within each sub-theme does not collectively total

to 31. Each of these themes is discussed in detail, before connections to other university modalities are drawn in the final paragraph.

Ten articles drew on topics of incorporating holistic, interdisciplinary approaches to sustainability education and distributing leadership as a result of pedagogical interactions. For instance, some of the literature reports on partnership projects between universities and other institutions for preparing students to become interdisciplinary leaders (Bowser et al. 2014) and draws attention to implementing a distributed leadership methodology so that universities operate more as ‘communities of practice’ (Davison et al. 2014; Pharo et al. 2012; 2014). Other articles draw attention to how interdisciplinary partnerships in teaching sustainability education help students to gain a more sophisticated understanding of climate change, for instance through the development of collaborative concept maps for improving scientific literacy and building a broader perspective (Correia et al. 2010). Pharo et al. (2012) argue that just as important as recognising the benefits of interdisciplinary learning is recognising the financial and other resources teachers require to collaborate in these ways, while Selin (2016) warns that the rich teaching and learning opportunities which ‘environmental summits’ such as UNFCCC’s Conference of the Parties (COP) can support unfortunately face normative, structural, and other barriers.

The necessity of holistic learning and helping students to better recognise the interdependent relationship between human beings and the natural world was also emphasised in these articles (Lehtonen et al. 2018), as some authors drew attention to the value in incorporating contextually diverse insights (Perkins et al. 2018) and multiple-discipline student research groups into the learning process (Otto 2017). Interestingly, Joyner-Armstrong et al. (2016) provided an account of the pupil experience to examine the perceived impact of cross-curriculum sustainability education and suggested that the informal practices and values set by the university are quite significant to students’ appreciation for the topic. Generally, the literature demonstrates that the sense of collective responsibility which arises when university faculty from various departments introduce interdisciplinary methods to delivering sustainability education is an important component to how pupils learn and take responsibility for these issues themselves.

Of these ten articles which highlighted holistic and interdisciplinary approaches to pedagogy, eight empirically evaluated the effectiveness of applied interventions. The most common ways in which impact was demonstrated was through students’ increased awareness and shifts in perspective. The strongest example was Joyner-Armstrong et al. (2016), who explored lived university experiences in the USA to understand the transformative potential of their multi-disciplinary philosophies and pedagogic approaches to sustainability education (of which climate change was a key facet of their analysis). The authors discussed pedagogical processes in conjunction with institution-wide curricular development and emphasised how curriculum design can generate the holistic and engaging teaching of sustainability issues. Students benefited from acquiring a range of academic and professional skills; for example, ‘new capacities’ for empathic decision-making, anthropological appreciation, science literacy, and cross-subject collaboration.



Bowser et al. (2014) evaluated cross-disciplinary impacts to student knowledge and understanding in the context of project and place-based learning activities, a sub-theme which is discussed below, involving university partnerships for exchanging resources and co-organising community and field learning experiences. In addition to students' reporting a broader appreciation for sustainability-related issues through these networks, Bowser et al. (2014) also included testimonial evidence of change to behaviour: students said they were more capable of effectively assisting public land and natural resource managers in matters of sustainability. Other ways through which impact to student awareness and/or attitudes are demonstrated include: evidence that concept maps (Cmaps) promote scientific literacy and thus deeper understanding of sustainability-related topics (Correia et al., 2010); teachers' testimonial evidence of change to students' learning, interest and enjoyment of sustainability education after incorporating COP-21-related content (Selin, 2016); and improved learning outcomes of online 'living with climate change' storytelling between heterogeneous groups (Otto, 2017).

Three related articles showcased institutional systematic change to teaching and learning after introducing interdisciplinary pedagogic interventions. Pharo et al. (2012) reported the (in) effectiveness of a cross-discipline teacher network established in an Australian university to improve student learning of climate change. While this experiment led to some informal professional development and spawned a series of small initiatives, including a student-devised unit devoted to climate change, many teachers found it difficult to commit to the network without established leadership and resources. This served as preliminary research for Pharo et al. (2014), which expanded the idea to four universities and found that informal institutional connections can better support interdisciplinary teaching of climate change through key factors: designating leadership, provisions for applying contextually appropriate practices, and identifying opportunities for teacher innovation and leadership within their existing roles and the structures of their institutions. Davison et al. (2014) then devised a 'distributed leadership methodology' for facilitating the kinds of collaborations and initiatives which these teaching networks need to be effective. Participants from each university used this model to successfully overcome the initial reported barriers to interdisciplinary teaching of climate change and sustainability. Outcomes included collaborative and peer-led professional development, contributions to large-scale institutional transformation, and curriculum reform.

A total of 14 articles focused heavily on real-world application of concepts, action or immersive learning experiences, and involvement with the local environment or community. Several of these, for instance, suggest that relating theories to the actual lives of learners and allowing them opportunities to draw purposeful connections with the environment are significant pedagogical dimensions to teaching about climate change. Bowser et al. (2014) illustrate an example of place-based learning, in this case using the Rocky Mountains in the USA, and devising field experiments and internships with local industries as ways of encouraging students to become involved with existing sustainability projects. 'Thinking locally' is a recurring theme, whether by focusing on practical skill

building and collaboration with regional businesses (Booth, Aben, et al. 2020), highlighting the distinctions in utilising specifically local, as opposed to global, examples of the biological consequences of climate change (Theobald et al. 2015) or enhancing student engagement in their immediate environmental context with action-oriented and experimental learning techniques (Dittmer et al. 2018). Jay et al. (2019) is unique as it examines the relationship between teaching students about carbon foot printing and these individuals' subsequent food choices.

The role of the learner as especially active in their education cannot be understated here, as many articles stress the importance of project-based, interactive, and student-centred pedagogies (Morrison et al. 2020; Perry and Thompson 2019; Radaković et al. 2017). This can be accomplished, some suggest, through orchestrating simulation activities, whereby learners become somewhat immersed in the issues they are exploring through role play scenarios (Doran 2016; Matzner and Herrenbrück 2016; Pettenger, West, and Young 2014; Richardson et al. 2017; Lysack 2009). Another author addressed kinds of service learning opportunities through which learners exercise degrees of autonomy and decision-making through a study on student-devised pop-up studios for evaluating public attitudes (Micklethwaite and Knifton 2017).

Each of the articles involving actual or immersive involvement in climate-change related issues empirically evaluates the effectiveness of applied interventions. One of these overlaps with the subtheme of holistic and interdisciplinary pedagogic approaches and has already been discussed (Bowser et al., 2014); another overlaps with the subtheme of online learning and is addressed later (Doran 2016). Again, impact is primarily demonstrated through contributions to knowledge and transforming points-of-view.

Five of the articles which focus on real-world application and experiences discussed changes which were industry- or field-specific. In Micklethwaite and Knifton (2017), the orchestration of a pop-up, interactive studio for the London public developed students' capacities for Sustainable Design, including how to respond creatively to the contemporary challenges of climate change and sustainability and to successfully engage with ordinary people about them. Pettenger et al. (2014) measured gains to factual, conceptual, procedural, and metacognitive knowledge in students of international relations and politics in the USA and Canada, respectively, following the introduction of a role play simulation pedagogy. These findings illustrate individuals' multi-level understandings about the ways in which these areas intersect with the climate emergency. Among nursing and midwifery students in the UK, scenario-based learning approaches led to changes to attitudes towards sustainability and climate change, and how they can be infused into the curricula, as well as increased knowledge regarding the management of natural resources and waste disposal in their fields (Richardson et al. 2017). Perry and Thompson (2019) observed a discernible growth in student understanding of ecosystem-based watershed management in a changing climate after using an interactive capacity development tool. Using the approaches of action learning and 'public pedagogy', or ways of engaging with concepts in one's community, Booth, Aben et

al. (2020) demonstrate increased student understanding of, and applied skills towards, regional businesses' reduction of greenhouse gas emissions. Because of the partnerships established with local businesses and pathways for students to directly assist them in reducing their carbon footprint, this last article also provides evidence of student involvement in the local context.

Three other articles demonstrate some degree of impact to student knowledge and/or attitudes more broadly. Using a large-scale, university trial, Theobald et al. (2015) measured the effects of university local contexts in teaching climate change. They reported a 45% increase in students' conceptual knowledge, stronger attitudes that climate change would affect their lives, more willingness to amend their individual behaviour, and stronger support for government intervention. This article was unique in that it drew gender distinctions in teaching about climate change: for instance, women were found to learn best from local, as opposed to global, biological consequences, and were more willing than their male counterparts to change their behaviour. Dittmer et al. (2018) found that through participating in a Youth Leading Environment Change (YLEC) educational programme, young people of university age successfully built upon existing environmental knowledge and developed new action competencies. Looking to increase engagement specifically, Morrison et al. (2020) found that in-class dialogue was most beneficial to this dimension of learning about climate change, and that this was especially true of non-science majors.

While three additional articles which described real-world pedagogies met the criteria for demonstrating evidence of change, their quality of evidence is less robust. Two gathered only testimonial evidence of change: Matzner and Herrenbrück (2016) of student knowledge after a series of collaborative Model United Nations (MUN) simulations; Radaković et al. (2017) of student interest and attitudes following practical environmental and climate change learning activity. Meanwhile, Lysack (2009) relied on informal conversations with participants, aged teen to 70+, who attended a teach-in event about global warming. He concluded that individuals benefited from the event's reflective and dialogic processes, which allowed them to develop new understandings of viable solutions to the issues raised, as well as to gain a stronger sense of empowerment for effectively communicating their concerns. Also spotlighting the importance of personal relatedness to these issues, Jay et al. (2019) stands apart because it demonstrates actual behavioural changes to students' dietary habits and carbon footprint after introducing an academic course, 'Food: A Lens for Environment and Sustainability', on the implications of food systems for climate change.

Seven articles discussed the use of online learning platforms and new technologies for the teaching and learning of climate change and sustainability education. Burch and Harris (2014), for example, discuss the development and delivery of free MOOCs as a new web-based platform for encouraging dialogue, collaboration, and contribution to learning. Similarly, Lehtonen et al. (2018) incorporate online course materials, referred to collectively as Climate.now, for showcasing a kind of interconnected pedagogy. De Gaulmynn and Dupre (2019) address more specific needs: the former for

platform-independent freeware tools for teaching Earth signal analysis by developing new innovative software technology, 'Java-Digital signal Processing/Earth Systems Edition' (J-DSP/ESE), and the latter for new sustainable performance simulation tools, such as the Easy Approach for Sustainable and Environment Design (EASED), to enhance sustainable design education. Meanwhile, two articles considered the strengths and limitations of pre-existing technological methods, for instance global climate models (GCM) in teaching anthropogenic global climate change (Bush et al. 2019), or the use a flipped classroom to enhance students' learning of climate change-related concepts (Tomas et al. 2019). Two articles were focused on immersive learning experiences for students: Otto (2017) considered how digital storytelling uncovers various 'lived experiences of climate change', while Doran (2016) drew on a 'Climate Interactive' tool which allowed law students to experience real-time legal negotiations in preparation for their careers in sustainable development.

Among the articles concerning pedagogical application of digital technologies, seven empirically analysed the effectiveness of applied interventions to improving knowledge and perceptions of the climate crisis. There was evidence from these articles of how education technologies support students' learning around several key areas, drawing from local and international data sets. Of the smaller-scale studies, Doran (2016) measured positive outcomes of a web-based experiential learning tool, 'World Climate' Negotiations Simulation¹¹, to postgraduate students' understandings and appreciations of the complexities of climate change negotiations. Similarly, Tomas et al. (2019) reported that students' successful learning of new science and sustainably concepts necessitate degrees of teacher-led instruction and facilitation to complement a flipped classroom model. The context for this study was pre-service teacher education but the authors framed the benefits of effective blended learning to higher education more generally. Finally, de Gaulmynn and Dupre (2019) found that use of a tool which simulates sustainable performance of built environments can benefit architecture students' learning about innovative and sustainable design when they work as teams.

Within the context of using digital platforms and technologies as pedagogical tools, three other articles measured changes to knowledge and perceptions of the climate crisis across a wider, global backdrop. Otto's (2017) study, for instance, took place over a two-year period and illustrated how the application of digital storytelling enhanced a range of learner competencies and spurred collaboration among groups of disciplinary and cultural differences. Bush et al. (2019) offered testimonial evidence of change through exploring geography teachers' attitudes towards employing realistic climate models in their classrooms. Their data from six continents and various higher education and research institutions suggest that the use of the National Aeronautics and Space Administration (NASA) Goddard Institute for Space Studies (GISS) Educational Global Climate Model (EdGCM) improves students' understandings about the geographical process of anthropogenic global climate change. Finally, Burch and Harris's (2014) pre- and post-survey data from thousands of participants in multiple countries indicate that its MOOC platform develops individuals' climate literacy by increasing



their knowledge base and moderately affecting their perceptions towards the threats of climate change. The authors suggest the likelihood of an 'egalitarian communitarian' mindset, meaning that the population's sense of risk will grow with increased knowledge of the topic.

Four articles identified degrees of student unpreparedness and areas of improvement pertaining to existing educational or training programmes. The topics in this category ranged from evaluating what appear to be unfavourable trends in science textbook content (Yoho and Rittmann 2018), confronting biology students with the degree of scientific consensus on climate change (Sloane and Wiles 2020), analysis of existing teaching-learning programmes in Malaysia (Reza 2016), and establishing a need for sustainability literacy as part of professional surveying programmes (Dent and Dalton 2010). Of these articles, Sloane and Wiles (2020) demonstrated evidence of applied change to student attitudes and behaviours after introducing tasks for engaging with scholarly literature on climate change. Though none of the student participants in this study denied climate science prior to the intervention, their content knowledge and ability to discuss it were both improved, thus illustrating 'the importance of preaching to the choir' (p. 594).

In summary, these articles offered a range of pedagogical approaches to the crisis, the majority of which (25 of 31 studies) captured evidence of change, predominantly in terms of shifts in student knowledge and attitudes. There is some discernible overlap between 'pedagogy' and other major typologies of university responses to climate change, the most obvious of which are noted here. Four articles reasonably coincide with the category of 'community engagement': 1) Booth, Aben, et al. (2020) involves student involvement in carbon footprint analysis for local businesses, 2) Bowser et al. (2014) highlights efforts to establish internships and long-term networks between students and local businesses and industries working towards environmental sustainability and 3) the individual 'leadership network for climate change teaching' established at the four participating universities in Davison et al. (2014), which emerged from an earlier pilot project (Pharo et al. 2014), deals with university collaborations and professional development. One article bore some importance to the category of 'campus operations': Jay et al. (2019) addressed the effects of a food-based environmental science course on reducing students' carbon footprint. Pedagogies of course are implicated in how teacher education is delivered; the following section synthesises articles with this focus.

6.1.3 Teacher education

Four articles were synthesised under the theme of 'teacher education' as a university response to the climate crisis. Within this broad theme were concepts related to interdisciplinary and transformative approaches to teacher education, emotional and interpersonal dimensions to pedagogy, and neoliberal agendas and challenges. Three nations were represented: Germany (with two articles reporting on the same study), Turkey and the USA. The articles generally adhered to discussions of local policies and

practices with potential implications for, but not immediately tied to, global responses to the climate crisis.

These articles focused on optimising university education programmes for aspiring teachers, either by investigating the effects of inquiry-based activities on knowledge acquisition and attitude development towards global climate change (Namdar 2018), or how to measure student teachers' procedural knowledge for combating biodiversity and climate change (Richter-Beuschel, Grass, and Bögeholz 2018; Richter-Beuschel and Bögeholz 2019). One more closely examined professional development of existing educators by exploring how thought processes inform individuals' teaching about climate change (Hestness et al. 2017).

The ways in which these articles demonstrate evidence of impact most widely consisted of systematic improvement to teachers' content knowledge and skills for the effective teaching and learning of climate change in schools. Two of the four articles in this sub-theme exclusively focused on the un/successful outcomes of standalone programmes or interventions (Hestness et al. 2017; Namdar 2018). Most of the data generated in this category was small scale and can best be appreciated as localised, preliminary research into how to positively inform student teachers' understandings and teachings of climate change. One focused on general ways of improving a training course, such as incorporating inquiry-based learning to aid teacher preparedness (Namdar, 2018). A second emphasised theoretical concepts, such as learning progressions (LPs) (Hestness et al., 2017) to generate ideas about what future-oriented ways of thinking and actions are required in responding to climate change-related issues. A final two complementary and sequential articles (Richter-Beuschel, Grass, and Bögeholz 2018; Richter-Beuschel and Bögeholz 2019) made a more nuanced contribution to the theme of 'teacher training' by differentiating between types of trainee knowledge necessary for developing Sustainable Development (SD) competencies (including climate change): situational, conceptual, and procedural, and refined an innovative process for measuring distinctly interdisciplinary procedural knowledge.

Within the education modality, a number of key themes emerge across the sub-themes of curriculum, pedagogy and teacher education. The first is the diversity of thinking about the climate crisis within this modality, both in terms of the disciplinary coverage but also in terms of forms of learning. A wide range of pedagogical tools were also evident, including new forms of technology but also leveraging new kinds of partnerships and human connections. There was also a diversity of methods deployed to capture evidence of change across this modality, but perhaps with some important caveats: we might assume as educators that knowledge leads directly to climate action, but this was not always proven, and more research on the link between knowledge and action is needed.

6.2 Knowledge production

In considering the 'research' function of the university, which engages with knowledge production, we were interested in articles which involved reflection about research, rather than solely reporting on the

findings of the research itself. The 'knowledge production' function of the university discusses not the transmission or facilitation of knowledge but rather its generation (McCowan 2020, 7).

The three articles synthesised directly under this theme discuss work by academic staff rather than research or scholarship generated by students or community members. None of the articles synthesised in this review offer meta-reflections of the processes behind developing new technologies or broader forms of innovation. One article offered analysis of publication data and citation practices in South Africa (Czerniewicz, Goodier, and Morrell 2017). A second drew on research in Spain to compare observations of climate change impacts reported by indigenous peoples and local communities with scientific measurements of such impacts (García del Amo, Mortyn, and Reyes García 2020). The third was a multi-country study, drawing on online survey data sent to 12,000 email addresses in 48 countries spanning five continents (albeit with a low response rate (7%) and under-representation from African universities and scientists in the final sample of 82 responses) to explore barriers and potential for implementing climate change research at universities (Leal Filho, Morgan, Godoy, Azeiteiro, Bacelar-Nicolau, Veiga Ávila, et al. 2018).

These three articles were all concerned with the power dynamics of knowledge production and the relationship to institutional research processes. The most explicit of these drew on a theoretical frame of Southern theory, writing "from the outside in" (Czerniewicz, Goodier, and Morrell 2017, 391), to interrogate the ways in which the use of social media and online technology has the potential to democratise global knowledge around climate change and challenge the "structural Northern bias" present in academic publishing and citation practices (p. 388), offering a pathway to impact for enhancing the possibilities from research in these institutions. In the article, material challenges associated with resources for academic production were linked to ways in which material conditions shape ideas: "addressing the challenge of reducing poverty at the same time as emissions creates a fundamentally different reality" (p. 400). While resources and funding were underlying concepts in all three articles, the socio-politics of economics behind research agendas were not the focus. Articles which focused on funding as a metric of shaping research agenda were notably absent from within this theme of the review, although of course implicated in the ways in which the structural Northern bias noted by Czerniewicz, Goodier and Morrell (2017) operates.

A second dimension of the theme around the relationship between epistemic dynamics and the potential impact of the 'knowledge production' function of universities was how the privileging of 'hard science' and 'emissions' within the emerging field of research into the climate crisis can work to exclude both indigenous perspectives and Southern knowledge (García del Amo, Mortyn, and Reyes García 2020; Czerniewicz, Goodier, and Morrell 2017), as well as shaping the kinds of institutional and systemic structures of higher education institutions (Leal Filho et al. 2018).

None of these articles offered substantive evidence of the effectiveness of knowledge production within higher education, although each

suggested pathways to more effective impact, as well as revealing some of the constraining and enabling factors that shape these pathways. Equity within publishing environments were seen as key pathways to impact by two of the other articles in this modality, as well as specific institutional support for academic engagements with media, policy networks and interested communities (Leal Filho, Morgan, Godoy, Azeiteiro, Bacelar-Nicolau, Veiga Ávila, et al. 2018; Czerniewicz, Goodier, and Morrell 2017). For the respondents of the survey conducted by Leal Filho and colleagues (2018), multi-, inter- and trans- disciplinary work through university hubs and networks also represented a pathway to increased impact for research within universities, moving to issue-oriented or problem-oriented work that would facilitate dialogue and connection, and simultaneously transform teaching content and pedagogies. Connection was also identified as a pathway to impact through the inclusion of indigenous communities in monitoring climate change by García del Amo, Mortyn and Reyes García (2020).

In addition to these three articles, there were a further eleven articles that reflected on research communication and collaboration with community stakeholders that we have synthesised in the community engagement modality of the university (in part 6.3.2, below), all of which relate to the dynamics of research dissemination and co-production, and two of which provided evidence of positive change.

There were no articles captured by our search terms, however, that contained meta-discussions of how different research methods or paradigms are (or should) be used for understanding the climate crisis. This may be a reflection of the fact that we did not include 'research' as a separate search term, as we did for, e.g., 'campus'. The absence of articles that contain meta-discussions of the research function of the university, however, does suggest that where articles exist which reflect on the meta-processes of climate research, they tend not to be focused on the implications for universities as institutions.

6.3 Community engagement

Of the five modalities in the university, the most disparate was a selection of articles which explored questions of 'service delivery', 'community engagement', 'outreach' and 'extension'. A total of 36 articles were synthesised under this theme, with links drawing out to each of the other modalities of the university that form part of this synthesis. Given the diversity of ways in which universities can reach outside their walls, this diversity of articles around the theme of 'community engagement' was to be expected, and echoed in other systematic reviews (Findler et al. 2019).

This modality thus represents different forms of connection, partnership and collaboration. Five articles considered partnerships across educational systems. Three of these focused on partnerships between multiple universities and their respective community-based stakeholders, including both South-South collaborations and North-South networks. A further two explored the ways in which university faculty and students reached out to schools, focused on



the primary and secondary level respectively.

Another six articles considered forms of 'real world' pedagogies discussed in the pedagogy modality above, theorising 'win-win' collaborations for both faculty and students, and the communities in which they were working. Related to the knowledge production function of the university, eleven articles discussed regional collaborations with community-based stakeholders focused on enhancing research dynamics and communication strategies, often exploring how current and future dialogue between evolving groups of climate researchers, decision-makers and practitioners can best be facilitated, or conversely what barriers exist to making this an effective pathway to impact. Seven articles considered similar questions of research and community collaboration, often through a communications lens, but with specific reference to extension universities in the context of the USA. A further two considered the situated role of the university but with connections to urban settings, while one article explored the university as actor in climate-mitigation projects, asking whether proximity affected how such projects were received by local communities. Finally, four articles were focused on the ways in which universities can support policy-making processes, whether through direct engagement through co-production processes or roles for universities as facilitators and trusted brokers of discussion.

Reflecting the geographical focus of articles in the systematic review as a whole, 19 of the 36 articles in the community engagement modality were written with a focus on the USA. Of these, one article reflected on partnerships with countries in Africa, but written from the perspectives of an academic affiliated to a North American institution. Another considered a collaboration with between Canada and the Caribbean, including authors from both regions. Only one article considered a South-South collaboration. In the single-context studies, the Anglophone Global North was further dominant with three articles each from the UK and Canada, and one article focused on Australia. Six articles focused on Northern European contexts: two in Italy, two in Spain, one in France and one in Switzerland. A final one article focused on Japan, and one on South Africa.

Methodologically, qualitative case studies in both single and multi-sited studies predominated in the community engagement theme (22 of 36 studies), drawing on interviews, personal reflections, workshop evaluations, qualitative surveys, documentary analyses, and organisational ethnographies to explore the question of community engagement. These studies did not necessarily include all actors in their sample, however. For example, one study explored the impact of a community engagement project but only in terms of impact on students, without including the indigenous leaders, parents and teachers who had also participated in the actions. Quantitatively, six studies assessed survey or questionnaire data, but there was also a study which measured climate impacts through water flow. Eight studies deployed mixed methods.

6.3.1 Partnerships within education systems

Three articles synthesised under the community engagement function of the university considered partnerships between universities. All three of these partnerships included international collaborations, and bridged the education, research and community engagement functions of the university. Two were partnerships between the USA and African contexts. The first of these considered a longstanding partnership between the author's own US university and research and education networks across sub-Saharan Africa, particularly through the work of the Association of African Universities (Bothun 2016), understanding networks both in terms of connected universities and in terms of internet connectivity. The article thus identified improved ICT connectivity as an important pathway to enhancing collaboration, knowledge and academic capacity. A second article focused on networked universities considered climate change projects in a 'live lab' in the Gambia, through reflections of an academic also based in the USA, in terms of global youth work. While the author identified such projects as a pathway to respond to climate change, specific empirical evidence of change was not included in the article (Sallah 2020). The third university network was a South-South partnership of academics reflecting on a multi-site case study of four South American universities (in Bolivia, Paraguay, Uruguay and Venezuela), pulling together a range of literature and testimonial evidence for the importance of networks, interdisciplinarity and stakeholder participation as pathways for HEIs to respond effectively to climate vulnerability, impacts and adaptation (Nagy et al. 2017). The breadth of the multi-site case study, however, meant that the depth of the evidence relied on cited articles, and so the findings were reasonably top line in nature.

Two articles considered work in which university students and academics reached out to primary or secondary schools. While both of these articles provided evidence of change, the research constituency varied, through surveys, student evaluations and/or reflections on practice. Asherman et al. (2016) explored partnerships between universities and schools, through a case study in which Master's students in a French university built a model to communicate the effects of carbon to students during a science festival. Through a questionnaire and survey with 267 students from a university and a primary school, the study found that visually simple and hands on experiments both stimulated student interest in science while improving awareness of the challenges of climate change. The second article under this theme integrated research, cooperative extension and education in a large-scale five year project across the south-eastern USA to develop secondary education instructional materials on climate change and forests, engaging 50 faculty members across 11 universities, and partnering with a national environmental education programme for secondary school science teachers (Monroe and Oxarart 2019). This article found a range of evidence of the effectiveness of the approach, including increased educator confidence, knowledge gain amongst biology and environmental science secondary school students, increased student engagement and increased student skills in systems thinking and application of science. The involvement of graduate students in the summative and formative assessments

helped to build soft skills in research and collaboration with different stakeholders. Perhaps unsurprisingly, the authors identified both extensive funding and time as key pathways to this level of impact.

6.3.2 Partnerships beyond education systems

Six articles considered pedagogical dimensions of the relationship between academic and community partners, particularly in terms of perceived or actual benefits to students, with strong interlinkages with the four articles discussed above which focused on 'real world' settings (Booth, Aben, et al. 2020; Bowser et al. 2014; Davison et al. 2014; Pharo et al. 2014). Each of the articles considered here also included implications for the community stakeholders, whether in terms of cost-reduction and reduced greenhouse gas emissions, or the work of students feeding into municipal planning through service learning. All six were in Global North contexts: Australia, Canada (n=2), Italy, Spain, and the UK. Some of these partnerships were led by the community-partner: for example, a partnership initiated by a chamber of commerce in collaboration with a Canadian university (Booth, Earley, et al. 2020), in which qualitative evaluations highlighted benefits to both the institution and the wider community, including bi-directional increases in knowledge in which public pedagogy was located in community needs, shifts by local businesses to carbon neutrality, increased demand for sustainability education, and a sense of student agency. The importance of recognition of multiple knowledges and strongly functioning networks was identified as a key pathway to these effective collaborations, while also acknowledging the context of neoliberal climate policies that often place a greater burden on under-resourced individuals, firms and communities to act as agents of change (Booth, Earley, et al. 2020, 955). A second article also explored industry-informed pedagogies, but on a much smaller scale (a single workshop), with a focus on promoting graduate skills (Summerton et al. 2019). While the article included summative assessments to explore the value of these workshops, it was a kind of pilot, and the authors themselves acknowledged that "more rigorous assessment" is required to "transparently assess learning outcomes / gains to the students directly participating in the sessions" (Summerton et al. 2019, 2965).

Two articles concerned with 'real world' pedagogies evaluated projects that worked with community-based stakeholders to deliver reductions in greenhouse gas (GHG) emissions associated with energy use (Pacheco et al. 2019; Parker, Rowlands, and Scott 2003). Both considered these collaborations as 'win-win', in which students gained valuable hands-on experience, enhanced learning associated with 'real-world' problems at local levels, and/or training and employment opportunities, while communities gained knowledge and understanding of the issues, cost-savings associated with energy use, and environmental benefits through reduced emissions. For Parker, Rowlands and Scott (2003), there were clear links with the research and public debate functions of the university, arguing for an integrated approach to energy use projects that would connect in both theory and practice at disciplinary, scalar, stakeholder and thematic (issue-based) levels. Key to the success of the Canadian

project which they evaluated was the reputation of the university, adding trust and credibility to multiple stakeholder work (Parker, Rowlands, and Scott 2003, 178). Inter-disciplinarity was also a concern of the work by Pacheco et al. (2019) who argued for a concept of 'multidisciplinary active learning' in real world contexts, in their case for engineering students in Spain.

The final two articles which considered partnerships for pedagogies focused on experiential learning in Australia and Italy. Both missed an opportunity, however, to reflect on the community impacts of this work, instead conducting a small-scale survey with students (Whitehouse et al. 2017) or through reflection from the authors who were also the founders and instructors of the summer school which they were analysing (Raciti and Saija 2018). Both were specifically concerned with place-based pedagogies: through relational engagements with the sea supported by indigenous rangers (Whitehouse et al. 2017), or a project co-produced within a specific region in Sicily that aimed to foster emotional and tacit connections to land (Raciti and Saija 2018). As a 'story of practice', Whitehouse and colleagues provided small-scale evidence of the reported value of experiential learning (in terms of emotions and senses) in shifting student attitudes, as well as highlighting the importance of networks of stakeholders for working partnerships to build and expand the frames of educational capacity.

A set of 11 articles also discussed regional collaborations with community-based stakeholders, but focused on enhancing research dynamics and communication strategies, often exploring how current and future dialogue between evolving groups of climate researchers, decision-makers and practitioners can best be facilitated. All were based in Global North contexts, with the exception of one article which considered adaptation strategies for a network of researchers and coastal communities in both Canada and the Caribbean (Lane et al. 2013). Their foci were varied, and included disparate forms of climate adaptation and planning: for indigenous communities in the Arctic (Tremblay et al. 2008); for coastal communities in the UK, USA, Canada and the Caribbean (Stojanovic et al. 2009; Mulvaney and Druschke 2017; Lane et al. 2013); for a range of industry, government, humanitarian aid and development workers in Switzerland (Addor et al. 2015), or for stakeholders in water governance in Spain and the USA respectively (Compagnucci and Spigarelli 2018; Crow-Miller et al. 2016). Three articles in the US context narrowed the scope to consider specific dimensions of climate change and the engagements between scientists and decision-makers: towards conservation of terrestrial fauna (Ledee et al. 2011); in addressing climate-related wildfires (Errett et al. 2019); or through generating principles for effective communication strategies for land-management (Schweizer et al. 2009).

Each was interested in the process of supporting change through, for example, recognising plural knowledges and local ownership of research, diverse voices, navigating competing priorities and reflecting on structural constraints such as funding mechanisms. Indeed one article specifically contrasted 'process' with 'products' of research collaborations, emphasising the importance of getting both dimensions right for successful collaborations (Addor et



al. 2015). The majority reported on small-scale case studies of research partnerships and/or workshops designed to enhance communication. Some identified valuable tools in this process, such as collaborative modelling of impacts, knowledge gaps and data priorities that supported mutual learning (Ledee et al. 2011). Others identified important pathways for effective climate adaptation, such as integrated community-based monitoring through longstanding partnerships built on local ownership, collaboration and recognition of indigenous rights and knowledges (Tremblay et al. 2008). One article drew on theories of the triple helix model to argue that a common and shared vision between actors, transdisciplinary innovation and enabling policy environment would all act as pathways to support more impactful forms of collaboration (Compagnucci and Spigarelli 2018). Echoing these findings, Crow-Miller et al. (2016) found that a lack of transparent communication and trust, scalar mismatch and misaligned institutional expectations all acted as barriers to effect university-utility collaborations, making the case that time invested to bridge the gap between 'practical' and 'scientific' knowledge would act as a useful pathway to impact (Crow-Miller et al. 2016, 482). Questions of trust and disconnects between 'scientific' and 'local' knowledges were also seen as a challenge to collaborative research into coastal ecosystems and fisheries in the USA, drawing on small-scale qualitative interviews to highlight issues around credibility that served as barriers to impact (Mulvaney and Druschke 2017). In a multi-sited case study within a single state in the USA, a final article considered how interdisciplinary research teams could support a range of sustainability challenges. Through qualitative data sources, the authors identified three pathways to enhanced impact: emphasis on local places and short-term dynamics; iterative stakeholder engagement and inclusive knowledge co-production and links between knowledge and action shaped by organisational cultures that emphasise respect, adaptability and a tolerance for risk that values learning (D. D. Hart et al. 2015).

Within these articles focused on enhancing research and communication strategies within and outside the university, Addor et al. (2015) were unusual in that they both identified pathways to enhance the impact of collaborations between scientists and decision-makers, and provided evidence, through analysis of a small-scale opinion survey, that the workshop shifted participants' perspectives on addressing uncertainty. Lane et al. (2013) presented interim findings from a five-year project, of increased local awareness toward enhancing adaptive capacity and reflections on local decision making between researchers and communities. Linked to the pedagogy theme of this synthesis, they also found that giving university students applied real-world research opportunities developed students' awareness.

A sub-set of seven articles discussed local-level climate adaptation and planning from the perspective of academics and staff working at universities with specific extension mandates in the USA. One of these articles offered a theoretical basis for such work, generating principles for "usable science" through a theoretical review supplemented with an organisational ethnography which put these principles into context (Brugger and Crimmins 2015). Their article identifies the social capital and networks represented by extension

universities as a pathway for effective climate adaptation, drawing on understandings of the university as a 'convenor', 'knowledge-broker' (through iterative, two-way processes), 'translator' and 'mediator' of local-level adaptations, such as developing locally relevant drought- and heat- resistant crops, offering training in geospatial technologies to support climate-adaptive farming practices or bringing together stakeholders around management of forests. As the authors themselves note, however, the effectiveness of these multiple different actions was not formally evaluated, and "more systematic evaluation may be needed for programmes that support adaptation" (Brugger and Crimmins 2015, 35).

None of the other studies assessed the specific impact of extension programmes but were rather focused on generating principles for good practice, and/or mapping the barriers to effective action. Two mapped the priorities and barriers which colleges faced to effective action, arguing that for extension universities to fulfil their potential to contribute to local adaptations, additional fiscal and human resource investments were necessary (Fillmore, Singletary, and Phillips 2018), and that land-grant universities would benefit from better integration of research and extension funding and work streams (Tobin et al. 2017). Other articles focused on effective communication and co-operative learning, emphasising effective strategies for dialogue (Doll, Eschbach, and DeDecker 2018), highlighting the cost-effectiveness of extension educators working with farmers (Prokopy et al. 2015), or evaluating delivery methods for outreach, such as face-to-face interactions contrasted with online or electronic media (Thorn et al. 2017). A final article drew on two small-scale cases of workshops with a focus on at-risk coastal communities to consider how extension universities can shift from "trusted brokers of information" to "trusted brokers of dialogue or processes of engagement" (Cone et al. 2013, 347). Also identifying a pathway to impact, they found that certain conditions of respect and acknowledging the multiplicity of 'expertise' led both to participant satisfaction in workshops but also interest in future dialogue.

Four articles were focused on the ways in which universities can support policy-making processes. Two of these articles evaluated direct engagement with policy-makers through co-produced processes of delivering impact (Wesselink and Gouldson 2014; Taylor et al. 2016), and so can be differentiated from work to assess institutional policies within universities discussed in the governance section of campus operations below, while a further two articles considered the role of universities as a facilitator of climate mitigation and adaptation planning (Hillmer-Pegram et al. 2012; Iwami et al. 2020). These articles were published from diverse contexts: the UK, South Africa, the USA and Japan respectively. One article was notable for its detailed assessment of the ways in which it engaged with direct questions of impact, through research co-produced by a local policy officer in the UK engaging directly with a Sustainability Research Institute, in order to make the case for low-carbon investment (Wesselink and Gouldson 2014). This study, through interviews with policy offers (n=11) in a local authority, aimed to assess whether an academic report was used as evidence, and if so, how, and if not, why not. The authors found that the policy and political context determined to a large extent whether an academic study is 'usable', as well as raising the importance of the expertise and will

of individual policy officers. The article mapped out three different pathways to impact for academic research to contribute to policy: supporting framing of the problem through ideas and argument; providing data for pre-existing goals; and reinforcing existing consensus through supporting arguments. A second article argued for the importance of time and reflection cycles in the process of policy co-production, through explicit evaluations of a collaboration between a university and local municipality in South Africa (Taylor et al. 2016). They identified a range of pathways to bridging the science-policy gap, including confidence and ability of individual actors, and the importance of trust and good communication across different organisational cultures. Both articles thus critiqued linear approaches to knowledge dissemination in which research is communicated to policy-makers and actors at the end of a project. Taylor et al. (2016) also acknowledged the impact on students involved in the project, building specific capacities within the university of more than 25 BA, MA and doctoral level researchers, calculated through project-specific research publications as well as reflections and focus groups. Their article also looked at practice, by reflecting on effective land management strategies.

The other two articles focused on policy considered universities' role as an active facilitator, whether through supporting local residents to develop climate mitigation strategies at two scales of government (municipal and regional) within one state in the USA (Hillmer-Pegram et al. 2012), or as a social implementation organisation, hosting municipal adaptation forums and bringing together various stakeholders (Iwami et al. 2020). Hillmer-Pegram et al. (2012) explored how universities can contribute both to innovative methods to provide data for policy (echoing findings of Wesseling and Gouldson 2014), in this case through developing a new form of emissions inventory, the findings of which were shared with residents in iterative phases of community focus groups, to allow residents to generate and prioritise mitigation options. The authors found that these focus groups, as well as the successful approval of the plan, generated a range of effective impacts, including increase in community awareness and activism, and the space to challenge climate denials. They acknowledged, however, that the resolution generated by these outcomes only encouraged and did not mandate municipalities to take climate action (Hillmer-Pegram et al. 2012, 83). For Iwami et al. (2020) the success of universities' role as facilitator also depended on communication, emphasising the importance of clear guidelines for policy workshops from the start.

Like these policy studies which all saw universities as situated within specific geographical environments, two further studies worked with situated understandings of the university as a part of urban settings, both in Global North contexts, and with clear links to the kinds of themes emerging through the discussion of campus operations below. In the USA, one focused on exploring a rain project as an interdisciplinary higher education and community engagement model for sustainable stormwater infrastructure. Drawing out the implications of campus sustainability for the wider community, this article provides quantitative evidence of impact through scientific measurements of water quality and surface water flow (Ahn and Schmidt 2019). This article suggested that environmental literacy could be a positive outcome of such models, but did not specifically

assess gains in "ecologically literate citizens", or assess the "sense of community" that such projects can foster (Ahn and Schmidt 2019, 6). A second article drew on participatory methods to bring architecture students together with municipal planners in Italy to combine climate adaptation actions with other urban regeneration actions linked to cultural heritage (Boeri et al. 2018). The evidence of the impact of this university response to climate change, however, was limited, as only the "partial outcomes" (Boeri et al. 2018, 200) of the project were being reported on, and evaluations had not yet been conducted. The authors themselves reflected that the "episodic nature" (ibid.) of these kinds of actions limits fully sustained and sustainable connections between universities and their wider communities.

Finally, one article focused specifically on university-designed climate actions, exploring the psycho-social dimensions of university climate mitigation projects in the USA and providing evidence from psychometric analysis of 556 questionnaires delivered to local residents that physical proximity to university-led mitigation projects were more positively received by local communities, contravening popular discourses of 'NIMBY-ism' ("not in my back yard!"), but with the caveat that the extent of support depends on the type of proposed project (P. S. Hart, Stedman, and McComas 2015).

In summary, within the community engagement function of the university, there were a range of different connections with external communities, with communities defined both by place and by practice. Communication was a strong theme of this modality, cutting across community engagement for research, for supporting teaching and learning, and for enhancing policy and universities' climate actions. A concern, however, was the extent to which external actors were the subject not only of an intervention, but also were engaged as co-producers or planners, and whose voices were heard in the evaluation and perceived success of outcomes and impact. This modality revealed great diversity in terms of ways in which institutions can engage with external communities, but also raised questions of the scale and sustainability of these engagements, with many authors suggesting that time and funding offered barriers to impact and change, as engagement relied on fundamental characteristics of trust. A shift from seeing the university as 'broker of information' to 'broker of dialogue' was also evident in a number of articles, representing an important shift in how the universities' position is seen.

6.4 Public debate

Within the literature reviewed, we found relatively little that reflected on the role of universities in contributing to public debate. Ten articles were synthesised under this theme, although there were clear links to public debate both in the campus operations and the community engagement modalities which are discussed in more detail elsewhere (for example, through research partnerships between universities and communities that foster public awareness and policy change, or through institutional governance changes associated with faculty or student activism). Nine articles were focused on Global North contexts, with a predominance of articles



on the USA (n=6), Canada (n=2), and a final article comparing Canadian and Finnish media. Only one article considered public debate in a Global South context, looking at the experiences of students at twelve different universities across South Africa. Of these ten articles, two were supported by documentary analysis of media outputs, three by qualitative analysis from a legal perspective, one by qualitative research from a public health perspective and a final four offering qualitative and mixed methods case studies of activism around divestment from fossil fuels, generally led by student actions and campaigns.

One article analysed the news media debate on Arctic climate change policy in Finland and Canada from 2011-2015, finding in both countries that universities were central actors in climate discourses, not only making statements but receiving support from other actors for their statements (Kukkonen, Stoddart, and Ylä-Anttila 2020). The centrality of universities as actors in shaping policy debates as outlined by this article is certainly a pathway to impact on the crisis, but the article did not offer analysis of the effectiveness of universities in this context. Other examples of shaping policy which did provide evidence of impact were discussed in the community engagement section above.

Another two articles considered the socio-political context in which universities and academics work from a legal perspective, both published in the USA, by exploring the impact of open records campaigns (Ley 2018), and of public records laws which the author highlighted were being used to harass high-visibility climate scientists (such as Michael Mann) for politically-motivated reasons (Polsky 2019). Both provided qualitative evidence of constraining political factors for HEIs and individual faculty members responding to the climate crisis, through in-depth interviews with twelve university researchers in the USA who were exposed to open records campaigns against climate scientists (Ley 2018), or through three case studies describing the history and experience of particular scientists (Polsky 2018). Both found evidence of negative impact of such campaigns on individual scientists, arguing that such campaigns and legal mechanisms were over-burdening academics, causing them to change their modes of communication and threatening the enterprise and innovation modes of universities, raising important questions for academic freedom in this context.

A third article also looked at the media and socio-political context in which universities function, but from the perspective of the public health of undergraduate and graduate students in South Africa (El Zoghbi and El Ansari 2014). Through qualitative focus group and interview data, as well as participant-observations, this article found that students' well-being was negatively affected by the media's pessimist communication, and inadequate or restricted communication networks. They identified a range of platforms and partnerships, as well as access to innovative technologies and social media as key pathways to enhance students' agency in responding to the crisis.

The remaining articles in this modality all considered the divestment movement – mobilisations to pressure universities to relinquish their endowment investments in fossil fuel companies – through

research in either the USA or Canada. One of these traced the history of the divestment movement in the USA, reflecting on the ways in which external campaigns (such as those of the campaigner Bill McKibben) are in dialogue with student movements and vice versa (Schifeling and Hoffman 2017). While this article conducted extensive documentary analysis of media reporting, however, the role of universities in the fossil fuel debate was not their main focus and so evidence of the effectiveness of dialogue with external campaigns was not provided.

The final five articles were all related to activism focused on questions of climate mitigation. Almost all the authors were activists participating in campus-based climate change initiatives discussed in the articles, in which student-activists were both consuming and producing knowledge about the crisis, shaping the debate through moral and ethical concerns, knowledge and actions. Three articles (Grady-Benson and Sarathy 2015; Healy and Debski 2016; Franta 2017) focused on the fossil fuel divestment (FFD) movement based at campuses of HEIs in the USA. The second two explored FFD in Canada: one (Helferty and Clarke 2009) looked at the whole gamut of campus-based student-led initiatives, while Maina et al. (2020) examined key actions and tactics through which FFD campaigns were initiated and the key mobilising actors behind them (in this case, students, alumni and faculty), and measured the varying degrees of fossil fuel divestment action spread across 220 HEIs. Using a policy mobilities lens, the authors noted an upward trend in FFD campaigns at HEIs from 2010 onwards. They highlighted how students were the primary actors in terms of policy mobilisation (by using strategies such as petitions, sit-ins, rallies, and protests in both virtual and in-person modalities). Ultimately, the evidence from the article suggests that collaborative actions have – and could continue to – result in institutional governance changes, which in turn could influence some of the ways in which sustainability and climate change are addressed at a policy level more broadly.

Student campaigns fostered public debate by reaching beyond campus in diverse ways. For Franta (2017), the 'reaching beyond' consisted of taking the debate on FFD to the legal domain with the noteworthy feature of representation of future generations as a plaintiff, while also identifying the legal technicalities future student litigators may encounter when they challenge institutional investment decisions in the US courts of law. For two other articles exploring campus-based FFD campaigns in the USA (Grady-Benson and Sarathy 2015; Healy and Debski 2016), this 'reaching beyond' involved bringing in business-dominated communities, such as governors of HEIs with fiduciary responsibilities, to the discussion table mediated by an ethically driven, politicised focus on institutional investments in fossil fuel companies. Moreover, these two reviews also recognised that FFD campaigns were contributing to the wider debate in society by bringing about a fundamental shift in the perspective and discourses around climate change from a technocratic analysis of carbon emissions to a human-centred narrative that calls for systemic social and economic change (Healy and Debski 2016, 17). These reflections have clear implications for the governance modality of HEIs, and whether a compliance-oriented sustainability model or a more politicised focus is called for.

For the review of student initiatives across 65 Canadian HEIs on broader climate change (Helferty and Clarke 2009), contribution to the public debate came in the form of identification of categories of the student-led climate change actions on campus, and assessment of student participation based on Gauthier's (2003) levels of youth engagement. A noteworthy category of student initiatives was student-led multi-sectoral collaboration, which consisted of a university-based student group, university administrations, a non-governmental organization, a corporate entity, and Canadian provincial government. This category was noteworthy because of the diversity of collaborating entities, and its aim of supporting the collaborative planning processes across multiple universities for action on climate change. Moreover, by assessing student participation the authors concluded that while socialisation was necessary to initiate wider student participation in climate change actions based on campus, the best strategy for engaging students in climate change initiatives would be to have a shared power relationship between them and the other campus stakeholders, which would facilitate equal voice in decision-making in campus-related matters including policy.

In summary, within this modality, evidence was concentrated on universities' contribution to public debate mediated by student activism on climate change. Student initiatives enlarged the scope of the debate in a range of ways – from capacity-building, such as multi-sectoral collaboration for planning student-led climate initiatives across multiple universities, to more abstract, for instance, exploring the framing of students' moral responsibility towards future generations. A second strand of work considered the role of the media and the courts in shaping the ways in which academics and students felt able to respond to the climate crisis, offering mixed evidence of both enabling and constraining socio-political factors that shaped the possibilities for pathways to impact.

6.5 Campus operations

The final modality or sphere of the university which is relevant to responses to the climate crisis by universities does not relate to the core purpose of the institution around generation or transmission of knowledge, but rather about the operations of the institution and campus itself. This modality sees the university as both a community and an organisation (McCowan 2020, 8) which manages finances and human resources, and in some cases makes investments. A total of 37 articles were synthesised under this broad theme of campus operations, which includes both the physical infrastructure, and the policy and governance infrastructure of universities. In relation to university finances and how they are managed, there are clear links with activism and critiques around investments in fossil fuel industries, discussed above in the public debate modality.

6.5.1 Greening the campus

A total of 22 articles were grouped under the theme of greening the campus as a university response to climate change. Of these, some focused on the impact of built environment mitigation interventions

(n=8). Others provided a range of reviews and critical assessments of campus greening strategies (n=6). A smaller number of studies looked more closely at specific physical infrastructure adaptations for increasing renewable energy capacity and building campus resilience (n=3). Also included under the greening theme were articles which explored the relationships between campus greening strategies and their associated behavioural adaptations for sustainability from those occupying and interacting with the built environment of the campus (n=5).

The articles synthesised under the greening the campus sub-theme were also varied in terms of their methodological approaches. Dominant were studies using mixed methods (7), case studies (6), and surveys (5). A smaller number of articles used quantitative approaches (3) and documentary analysis (1).

The articles predominantly emerged from the US context (n=7), followed by others from Canada (n=2) and Australia (n=2). Also from a Northern perspective was Mazhar et al's (2017) article reporting on a study in the UK. Other articles spanned a wider range of territories, including Malaysia, Nigeria, Botswana, Mexico, Taiwan and Costa Rica. Four articles provided multi-country analyses which increased the geographical spread of evidence grouped under the campus sustainability theme. From an Ibero-American perspective, Perales Jarillo (2019) provided insight into an online educational model for sustainability spanning across five countries (Spain, Ecuador, Colombia, Mexico and Peru). Redfern and Zhong (2017) assessed the carbon management performance of various universities across the UK and China. A study by Adom̂ent, et al. (2019) examined the Green Office (GO) sustainability model by gathering data from universities in Germany, the Netherlands, the UK, Belgium, Sweden, and Italy. Further adding to the international landscape was Suwartha and Sari's (2013) study which focused on GreenMetric, a system of global ranking based on sustainable practices. The authors included data on conditions and policies related to campus sustainability from universities in 42 different countries, with the highest participation rate from institutions in the Indonesia (where the authors were based, and where the ranking originated), as well as in the USA.

The diversity of country contexts from which concerns about campus sustainability emerged demonstrates that efforts to address climate change at an institutional level are gaining traction. The impact of campus sustainability efforts was measured both by small scale studies focused on a single university context (for example, Marcell, Agyeman and Rappaport, 2004; Adewole, Agbola and Kasim, 2015; Baer and Gallois, 2018) and by wider studies involving multiple campuses and countries (such as Suwartha and Sari, 2013; Adom̂ent, Grahl and Spira, 2019; Perales Jarillo et al., 2019). In this way, the impact of campus greening strategies, educational models for sustainability, and other institutional efforts to drive forward sustainability could be considered as being institutionally, nationally, regionally and internationally situated. At the same time, the articles retained a core focus on the role of universities as 'key drivers of sustainable development' with a leading position and potential for impact in the wider climate change debate (Redfern and Zhong 2017, 193).



The theme of campus sustainability was explored using a range of theoretical perspectives. Swearingen White (2009), for example, drew from theories of organisational change and learning to develop ideas about the types of campuses which would be more likely to drive innovation in terms of climate change. With a basis in social psychological theory, two studies examined some of the behavioural aspects of climate change through research on energy conservation and reduction efforts of students across different university campuses in Canada (Senbel, Ngo, and Blair 2014) and one campus in the USA (Marcell, Agyeman, and Rappaport 2004). Other articles, however, did not draw as explicitly on theory to underpin their analysis.

Seven of the 22 studies under the greening theme demonstrated evidence of an effective intervention. Of these, four were based on small scale studies at single universities: two from the USA (Marcell, Agyeman, and Rappaport 2004; Pollard 2016), one from Nigeria (Adewole, Agbola, and Kasim 2015), and one from Mexico (Hoyo-Montaño et al. 2019). One other involved two universities, both in the USA (Waliczek, McFarland, and Holmes 2016). Two articles included multiple universities within their studies, but these were restricted to only the UK (Mazhar, Bull, and Lemon 2017) and Canadian country contexts (Senbel, Ngo, and Blair 2014).

The eight articles related to built environment mitigation interventions included three studies examining GHG and energy reductions at university campuses using case study approaches and a quantitative analysis (Coffman, 2009; Batisani and Ndiane, 2014; Hoyo-Montaño et al., 2019), with another two assessing the nature and performance of university carbon management plans through mixed methods and surveys, respectively (Mazhar, Bull, and Lemon 2017; Redfern and Zhong 2017). Three articles evaluated carbon and ecological footprints at universities using different methods including surveys and case studies (Liu et al. 2017; Uddin, Okai, and Saba 2017; Perales Jarillo et al. 2019). While Uddin, Okai and Saba's (2017) article found a proposed ICT framework to be effective in reducing university carbon footprints using surveys for expert evaluation, it did not ultimately assess nor measure the framework's implementation. Similarly, Batisani and Ndiane's (2014) work included a quantitative inventory of GHG emissions on a university campus in Botswana, yet beyond general discussions on raising awareness about climate issues, it reported no further evidence on effective interventions to reduce emissions. Liu et al.'s (2017) study examining the environmental impact of a university in China as well as Perales Jarillo et al.'s (2019) work describing the impact of online education models in relation to climate action in Spain – while both serving as a base of evidence for future campus sustainability planning – also did not provide evidence of effectiveness.

Two of these articles linked built environment mitigation interventions to effective interventions for climate change. Mazhar, Bull and Lemon (2017, p. 379) identified six 'critical success factors' that can contribute to effective carbon management processes within HEIs, as established through a mixed-methods approach which included a content analysis of institutional carbon management plans and interviews across the UK HE sector. The authors argued

that embedding these six factors (senior management leadership, funding and resources, stakeholder engagement, planning, governance and management, and evaluation and reporting) could contribute to effective carbon management at universities and for other organisations more broadly. Similarly, Hoyo-Montaño et al.'s paper (2019) presented results from the implementation of a pilot energy saving programme, analysing these through both environmental and economic impacts. Processes of retrofitting and automating light systems were shown to be effective in energy saving and in terms of financial payback.

Six studies involved both reviews and critiques of campus greening strategies. Three reviewed and reflected on university engagement in climate initiatives (Swearingen White 2009), campus climate change strategies (Atherton and Giurco 2011), and university commitments for sustainability (Baer and Gallois 2018). Three others provided more of a critique of university greening efforts, including a study that gathered data on campus climate change vulnerabilities and adaptation strategies (Owen, Fisher, and McKenzie 2013), another that evaluated a tool for ranking universities through campus greening strategies (Suwartha and Sari 2013), and one analysing the ways in which green office models on campus might reorient HEIs towards sustainability (Adom̄Bent, Grahl, and Spira 2019). None of these articles, however, focused on analysing the effectiveness of these interventions.

Three articles analysed physical infrastructure adaptations at universities. One study shed light on a university-based renewable solar energy project (Vaziri and Kellier 2009), while another described the integration of water quality management and conservation education on a university campus (Mitsch et al. 2008). One mixed methods study examined disaster responses and ways to build campus resilience through community-based climate change adaptation (Adewole, Agbola, and Kasim 2015). This article described structural and non-structural strategies taken at a university campus to build resilience, providing evidence of an effective university response to the crisis. Adaptations to conditions of increasing vulnerability to climate change impacts in Nigeria (in this case, flooding) included engineering interventions (e.g. river channel modifications) as well as the development of a formal flood warning system and improved building regulation enforcement.

Five articles discussed greening in terms of behavioural adaptations for sustainability, thus making stronger links to campus activities and university actors. For example, two studies assessed energy reduction behaviours on campus through voluntary and individual-level energy saving adaptations (Pollard 2016) and a campus-level competition to reduce energy consumption (Senbel, Ngo, and Blair 2014). At an institutional level, a mixed-methods study analysed the impact of an energy reduction marketing campaign at student residences in terms of student attitudes and behaviours with respect to the environment (Marcell, Agyeman, and Rappaport 2004). One article examined the extent to which there was community support for different carbon neutrality approaches at a university campus in the USA through a mail survey of 677 respondents resident in the university's 'host community' (McComas, Stedman, and Sol Hart 2011), whereas another used 660 surveys to measure the

relationship between participation in a composting programme on campus and students' demographics, environmental attitudes, environmental locus of control, compost knowledge, and compost attitudes (Waliczek, McFarland, and Holmes 2016).

Notably, all five articles related to behavioural adaptations for sustainability showed evidence of effective interventions. Marcell, Agyeman and Rappaport's (2004) article suggested that a small-scale pilot study to reduce GHG emissions at a university using social marketing methods in the USA had a greater impact on student environmental knowledge, attitudes, and behaviours for the experimental group (comprised of 16 students) rather than the control group (with 9 students). From the same country context, Pollard's (2016) research similarly documented the implementation of an energy-related technological behavioural intervention. There, an energy saving device was installed on university staff workstations to measure energy usage, while a survey with 143 participants (including university administrators, faculty and general staff) was conducted to assess sustainability awareness. The results showed positive influences on sustainability behaviour, as measured by an analysis of computer usage data and a content analysis of survey comments feeding back on the energy saving intervention.

Related to these studies was Senbel, Ngo and Blair's (2014) work in Canada analysing an energy reduction competition for students living at university residences. Results of the study found that the competition was effective in reducing energy consumption; moreover, student engagement was posited to be linked to the embedding of 'learning and discursive objectives' otherwise termed as 'entertainment engagement', which the authors argue is an effective way to overcome some of the social barriers to dealing with 'complex and intractable' problems such as climate change (pp. 91-92). Finally, through surveys at one university with a composting programme and one without one (both within the USA), Waliczek, McFarland and Holmes (2016) found positive correlations between compost knowledge and positive environmental attitudes – defined in this article as attitudes which result in environmentally responsible behaviours and habits – amongst students at the campus with an active composting programme.

Taken together, the articles synthesised under the 'greening' theme emphasised how campus-based initiatives and processes for climate mitigation and adaptation involve both infrastructural as well as socio-spatial dimensions. Structural measures aimed at informing and mobilising effective campus greening interventions were particularly reflected across the studies highlighted in the latter part of this section, thus suggesting that the behavioural and infrastructural dimensions that underpin campus greening activities play a key role in shaping sustainability activities on campus.

6.5.2 Governance

15 articles were included under the theme of governance as a university response to climate change. Within this theme were studies linked to policy and governance infrastructure across macro- (international), meso- (national) and micro- (institutional)

levels, each of which raised different findings about how universities develop, implement, and manage policies in relation to climate change. Two articles featured a macro-analysis of governance issues (policies on sustainable entrepreneurship and the role of university faculty in campus divestment) between two country contexts, comparing the USA with Germany and the USA with Canada. A third focused on Australia but drew out international comparisons, in considering the role of unions and collective bargaining in employment relations to enhance climate mitigation, finding that the higher education was the most likely sector to have enterprise bargaining agreements with environmental clauses (Markey and McIvor 2019). A final macro-analysis deployed an international survey to consider how HEIs were developing climate adaptation actions or plans, but with a sampling bias of countries in high-income Global North contexts, with 41% of responses coming from HEIs in Australia (Kautto, Trundle, and McEvoy 2018). Meso-level analyses involving two or more universities in a single country context were dominant in this theme (n=9), while micro-level analyses examined more specific institutional policies, sustainability practices, and divestment actions (n=4). Although many of the institutional-level commitments and policies were termed differently (for example, being referred to as climate action plans, sustainability reporting, or support systems), these overlapping terms broadly referred to similar policy processes within universities. This relative diversity of both methods and topics under this theme suggests that concerns and explorations around issues of governance in the literature are often context-based and can vary widely in scope and scale. Definitions of governance and governance approaches across the articles spoke to a range of proclamations, values, and priorities on both institutional and public policy levels. As such, many of the studies examining issues of governance overlapped with other modalities, particularly with the theme of greening the campus by highlighting the ways in which policies for sustainability and climate change at HEIs are negotiated, formulated, communicated, implemented, or evaluated.

Qualitative analyses of governance issues included seven articles that used both content and documentary analysis to identify and explore governance issues within and across universities. These included an examination of university sustainability reports (Gamage and Sculli 2017), a review of institutional policies around climate change in terms of academic mobilities and sustainability imperatives (Hopkins et al. 2016), a comparison of discourses in the media about university-industry relationships (McCartney and Gray 2018), an analysis focused on open letters of support for university divestment from fossil fuels (Stephens, Frumhoff, and Yona 2018), an exploration of policies supporting green jobs training in higher education (Kayahan Karakul 2016), and an examination of enterprise bargaining agreements to evaluate the percentage which contained 'environmental clauses' (Markey and McIvor 2019).

Further qualitative analyses included four studies that used a case study approach to look at governance through Climate Action Plans (or CAPs) (Abbott and Kasprzyk, 2012), an urban laboratory (Evans and Karvonen, 2014), educational initiatives aimed at



emission reduction (Molthan-Hill et al., 2020), and university policies for sustainable entrepreneurship (Tiemann, Fichter and Geier, 2018). Finally, O’Keeffe (2020) drew from 50 key informant interviews as the primary method to explore how some of the key challenges related to climate change (namely, urbanisation, climate change and food security) are being addressed by universities.

Of the 15 studies which had a governance theme, only four had quantitative approaches to examining issues around governance. Henderson, Bieler and McKenzie’s (2017) mixed-methods study combined a quantitative census of university policies in response to climate change with a qualitative content analysis of the policies themselves. Also using a mixed-methods approach combining a survey and interviews, Nursey-Bray et al.’s (2019) study examined university policies around academic travel, while Linnenluecke et al. (2015) examined policy and organisational responses to university fossil fuel divestment through a quantitative performance rating system. Finally, Kautto et al.’s (2018) international survey of sustainability and environmental managers (with one respondent from an academic) analysed responses from 45 HEIs to explore how many of these institutions had set adaptation goals, objectives or strategic statements.

The evidence in these articles spanned a range of country contexts, with a dominant trend from Northern countries (mainly Canada, Australia and the UK). Three articles emerged from the Canadian context (Owen, Fisher, and McKenzie 2013; Henderson, Bieler, and McKenzie 2017; McCartney and Gray 2018), while three had a focus on Australia (Linnenluecke et al. 2015; Gamage and Sciulli 2017; Nursey-Bray et al. 2019). Two articles addressed issues related to governance from the UK perspective (Evans and Karvonen 2014; Molthan-Hill et al. 2020). The remaining articles included studies from New Zealand (Hopkins et al. 2016), Turkey (Kayahan Karakul 2016), and Ethiopia (O’Keeffe 2016).

The wider debate around governance – at all levels – in the 15 articles tended to focus on concerns about mitigation, and to a lesser extent, adaptation for climate change (including, but not limited to, sustainability commitments, policies and efforts by universities). As an example, Molthan-Hill et al. (2020) used the case of a higher education initiative involving the measurement of organisational carbon footprints to highlight ways in which mitigation routes and tools can be scalable and discuss how such efforts help to deliver on climate-related SDGs. Relatedly, O’Keeffe (2016) identified the Climate Change Research Centre (CCRC) at a university in Ethiopia as having a focus on mitigation and adaptation to climate change, while Kautto et al. (2018) also considered both mitigation and adaptation strategies.

In keeping with the trend of studies highlighting how issues of governance were linked to climate mitigation efforts, Abbott and Kasprzyk (2012, p. 572-573) outlined the case of the American College and University Presidents’ Climate Commitment (ACUPCC) as an example of a ‘policy instrument’ designed to encourage HEIs to become zero-net GHG emitters. Another case study on a low-carbon urban laboratory involving local

stakeholders (city council members and property owners) and two universities in the UK illustrated how sub-local spaces can help implement government approaches to mitigation and adaptation (Evans and Karvonen 2014). Thus, while concerns for mitigation and adaptation were evident in the articles, there was a lack of attention on efforts of regeneration or transformation of governance practices in universities.

Of the 15 articles included in the review under this theme of governance, Henderson et al.’s (2017) institutional policy analysis in the Canadian context had a more direct and comprehensive analysis of whether, how, and to what extent educational institutions have engaged with issues of climate change through specific policy actions (and governance more broadly). Their analysis revealed that most university policies tend to be concerned with the built environment and campuses overall, whereas less attention is given to how governance as a response might overlap with efforts to enhancing research, outreach, or curricular agendas responding to climate change. Such findings were largely in keeping with the remaining articles, which drew attention to elements such as action plans, research groups, and reporting practices at universities rather than discussing debates about governance itself as a key factor in determining how and why universities might take up climate-related actions. Moreover, the reviewed articles indicated that there is a lack of scholarship emerging from the perspectives of governance actors themselves (e.g., policymakers, institutional managers, and other stakeholders).

Under the theme of governance as a university response to climate change, the articles were divided into those which drew from empirical evidence to theorise about the relationships between governance, universities, and climate change (n=14), and only one which demonstrated how governance interventions were effective (n=1). Eight articles reviewed the nature, content, and extent of policies as evidence of a university intervention through: an analysis of university sustainability reports (Gamage and Sciulli 2017); a review of climate change-specific institutional policies (Henderson, Bieler, and McKenzie 2017); a study on the correlations between state-level policies and climate policies enacted by HEIs (Abbott and Kasprzyk 2012); an article examining institutional policies and their relation to academic mobility practices (Hopkins et al. 2016); an overview of educational policies and their links to renewable energy job training through HEIs (Kayahan Karakul 2016); an analysis of the influence of different levels of governance in enacting change in a carbon-reduction initiative at an HEI (Molthan-Hill et al. 2020); an analysis of media discourses about decision-making in university funding (McCartney and Gray 2018); and an analysis of the role of employment unions in negotiating environmental commitments (Markey and Mclvor 2019). Two articles investigated the role of policy from a behavioural perspective by looking at faculty attitudes towards divestment through a documentary analysis (Stephens, Frumhoff, and Yona 2018) and faculty perceptions on international mobilities at universities (Nursey-Bray et al. 2019), while two others explored issues of governance in future-oriented scenarios and proposals through

an interview-based study (O’Keeffe 2016), a case study (Tiemann, Fichter, and Geier 2018). One considered both what kinds of adaptation initiatives existed, as well as some of the barriers to adaptation planning, identifying resources, institutional focus or will and the comparatively lower importance placed on adaptation as key concerns, as well as the complexity of future-risk. With important links to the community engagement theme, this article also identified the importance of local government processes as an enabling environment, drawing on the experience of five Australian institutions (Kautto, Trundle, and McEvoy 2018). Finally, one article looked specifically at shifts in divestment policies through an environmental, social and governance (ESG) rating framework within a single university in Australia and the extent to which this impacted the university’s holdings, rather than examine the effectiveness of the shifts themselves (Linnenluecke et al. 2015).

While these 14 articles provided multi-level insights on the theme of governance as an important dimension of campus operations, they neither identified nor measured the effectiveness of such interventions as institutional policies or sustainability statements. Only one article provided evidence of effective interventions. One case study on a low-carbon urban laboratory in the UK provided an example of how partnerships between HEIs and local governments can result in effective changes towards climate governance through strategic capital investments, including investment in infrastructure and research to develop the urban laboratory in partnership with a local university. Additionally, the study highlighted how processes of ‘recursive knowledge production and application’ often feed into policy development by generating data, applying it to policy, assessing results, generating further data, and making further revisions to policy (Evans and Karvonen 2014, 425).

The fact that only one article of 15 showed evidence of effectiveness suggests that the size and scope of the body of evidence around the theme of university governance remains limited. In particular, there was a pronounced shortage of macro-level data which spoke to cross-national and cross-regional evidence about the broader impact of policy related to higher education, and no articles discussing evidence of effective mitigation or adaptation strategies by universities in the Global South. As ever, we do not want to suggest that this work is not happening, but there is a paucity of literature published in English in the Web of Science about the work being done. As Latter and Capstick (2021) argue in their analysis of UK universities’ climate declarations (published after the searches for this review), policies on paper represent significant public aspirations and promises, but there is an important distinction between ‘warm words’ and action, and a further important distinction between specific commitments formulated in such governance infrastructure and a wholesale reorientation of universities’ purpose and practice (Latter and Capstick 2021, 6).

Our final concern in relation to the governance theme of universities are the ways in which this work at the policy level connects to other themes such as research, or teaching and learning. Deeper reflection that connected the experiences of university sustainability staff with academics and students was missing in this theme, suggesting that opportunities for whole-scale transformation

of the sector are being missed. As Kautto, Trundle & McEvoy (2018, 1274) argue in the conclusion to their article, more formal connections within and between universities, as well as increased holistic guidance from university networks supporting this work, would enhance these processes and begin to address some of the barriers to wholesale work.

7.0 A typology of change: measuring the impact of university responses to the climate crisis

The syntheses above have been divided into themes or university modalities, but there are of course, important connections between them. Of the 151 articles synthesised as part of this review, 26 spoke to more than one modality. Unsurprisingly, 23 of these 26 included some reference to community engagement, the modality in which the themes of connections and partnership were foregrounded in our discussion. None of the 151 articles which form part of this review, however, considered the university as a holistic institution. This is perhaps also unsurprising, as our emphasis on empirical data may have constrained the possibilities for data collected across all five modalities. Nevertheless, we think that this would be an important theoretical and empirical insight – how we might understand and provide evidence for a holistic approach to institutional responses to the climate crisis? This section of this report tries to answer this question, generating a typology of change from the 151 articles synthesised in this review, to consider what we have learned about how outcomes and impact of university responses have been measured.

7.1 A typology of change

To begin to generate a typology of change, as we discussed above in part 5.6 of this report, we first generated a list of the articles which we considered to provide some kind of evidence of change, which then formed the basis to the table in Appendix 4. This analysis generated six different types of change, which we categorised in the following ways:

i. **Epistemic:** this category of change included a deepening of knowledge and understanding of the climate crisis, and/or increased awareness about the climate crisis in general (including specific dimensions which may relate to discipline, e.g. the impact of the crisis on public health). An increase in general scientific competencies was also conceptualised as this kind of change, such as development of skills needed to analyse raw data or work across disciplines. Within these studies focused on measuring change in knowledge, understanding, awareness, skills or competencies, some studies focused on general awareness (such as increase understanding that climate change is happening) while others focused on discipline-specific knowledge (such as increased understanding of the impacts of the crisis on public health, or how to measure increased methane in the atmosphere through chemistry curricula).



ii. **Ethical:** this category included change in both individual and collective beliefs and attitudes, such as increase in personal connection to the climate crisis and/or those most affected, perceived confidence to take action, enhanced sense of collective social and/or governmental responsibility to mitigate climate change, sensitivity towards environmental issues or interest in following careers associated with the climate crisis.

iii. **Behavioural:** this category of change was focused on measuring actions undertaken in response to the climate crisis, e.g., measures taken to reduce personal carbon footprints, adjust energy or water use, or change diets. This category also included forms of activism, for example student protest.

iv. **Institutional:** this category of change underpinned institutions, whether the university itself or social institutions such as government or the judiciary. It included revisions to policies and laws, as well as teaching and learning strategies and systems, whether curricular or pedagogical.

v. **Structural:** this category of change was physical, and included changes made to buildings or other infrastructure (e.g., lighting). Some of these changes were aimed at climate mitigation (i.e., direct reduction of emissions), while others were aimed towards adaptation (e.g., adapting buildings in flood-prone areas).

vi. **Atmospheric:** this type of change was associated with mitigation and measuring emissions, but also often included measurements of cost-savings, whether for individuals, universities or companies. In this category we also included articles which reported on energy use reduction.

As table 12 below shows, the majority of studies measured epistemic forms of change, followed by attitudinal and behavioural changes. In the language of the guiding framework depicted in figure 1, these changes are all located in bridging actors, whether students, teachers, NGO and government representatives, policy-makers or the general public. They were often self-reported changes, measured by pre- and post- questionnaires or surveys. Epistemic changes were the only type of change to be found across all five university modalities, as figure 4 makes clear. The second set of changes related to systems and buildings, which were located in socio-political as well as physical infrastructure. Finally, a much smaller number of studies aimed to measure changes directly impacting the ecosystem.

Table 12. Documenting change

Type of change	Number of studies
Epistemic	61
Ethical	39
Behavioural	16
Institutional	12
Structural	2
Atmospheric	6

It is important to note that, to an extent, these categories mask the nuance represented by articles discussing change. This is particularly true in cases of epistemic change, the largest category of change. Across different modalities, many of the articles highlighted that not all forms of knowledge are associated with climate action, or indeed with effective climate action. Knowledge that led to increased pessimism was particularly problematised (see, for example, Duffy, Hammond and Cheng 2019). Other articles, particularly in the education modality, theorised types of knowledge, differentiating for example, procedural knowledge (Richter-Beuschel and Bögeholz 2019), investigating action competencies (Dittmer et al. 2018), or connecting knowledge with skills to highlight that not all forms of epistemic change produce the same actions or climate outcomes. Within the epistemic category, there are also levels of depth: some articles measured significant or substantive changes in understanding, while others may have measured only surface-level changes in awareness of the crisis. While we have grouped together all articles that were focused on epistemic change, we also want to emphasise that they represent a nuanced and diverse set of literature.

Furthermore, these categories of change are of course overlapping and inter-related, although the connections were not always made explicit within the reviewed articles. Behavioural change in particular tended to correlate action with increased knowledge and/or (positive) shifts in attitudes, particularly attitudes associated with self-efficacy, while reductions in emissions also tended to be associated with gains in understanding or shifts in a sense of responsibility. Connection between epistemic, ethical and behavioural change was not clear in all cases, however: one study in the education modality found that a curricular intervention enhanced students' understanding, skills and attitudes about historic interaction between human society and climate, and competencies related to science of climate change, but found minimal evidence of behavioural change (Nam and Ito 2011). Another in the campus operations modality found positive impacts on student environmental knowledge, attitudes, and behaviours but not statistically significant emissions reductions (Marcell, Agyeman, and Rappaport 2004). Only one study focused on change that was sustained, measuring students' actions through a survey administered at least five years after participation in a course (Cordero, Centeno and Todd 2020).

These examples offer a word of caution: the difficulties in providing substantive evidence of behavioural change associated with epistemic and even ethical shifts, and then further linking these with changes associated with emissions reduction, represents a challenge to assumptions in curricular or pedagogical approaches to the crisis. Broadening knowledge bases may be a necessary but not sufficient response by universities. Within the current context of evidence-based policy-making, we need to continue to push for creative ways of evaluating epistemic shifts. Meaningful epistemic change associated with the climate crisis is certainly taking place, but more is needed to develop robust methodologies to show that this is the case.

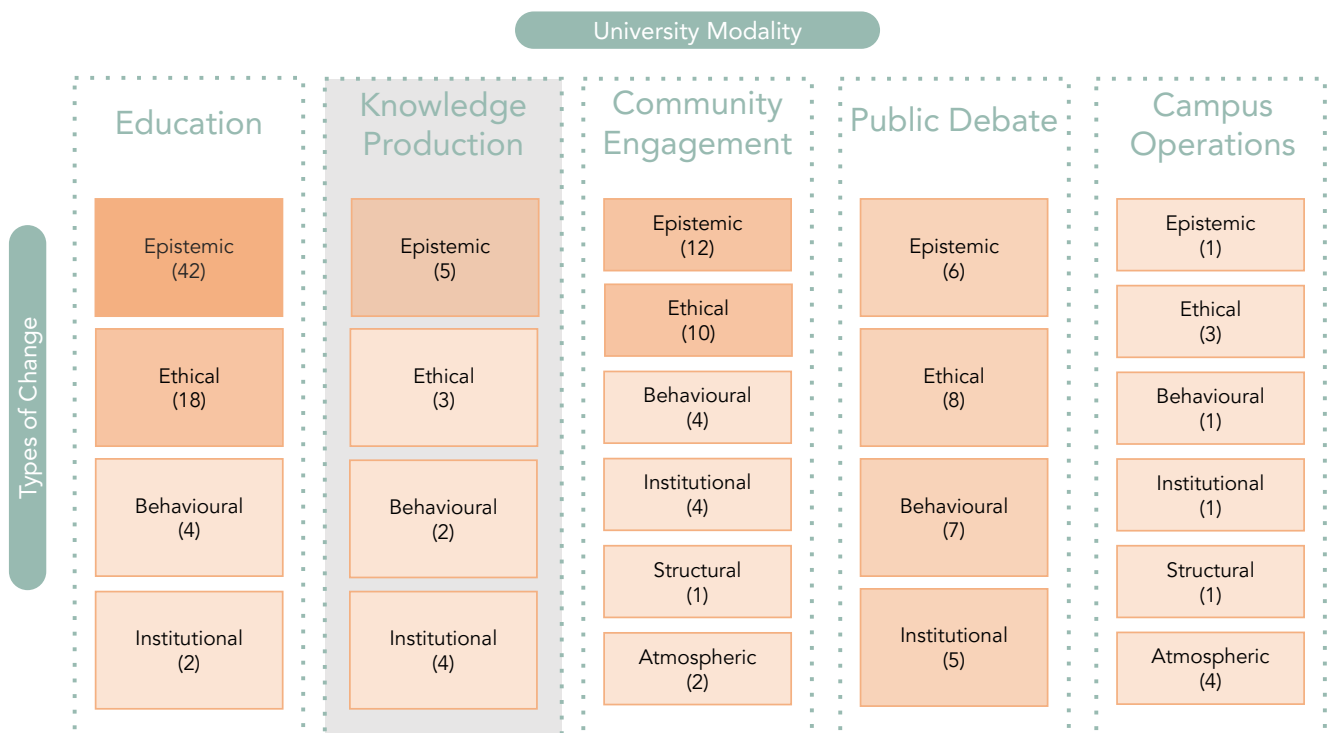
7.2 Evidence of change, by modality

We also considered the relationship between these six types of change and the different modalities, drawing on the analysis documented in appendix 4, and depicted in figure 4 below. This gives an indication of the concentration of evidence (as defined by number of studies) for each different type of change within the five modalities. It is important to note that this a broad brushstroke depiction of evidence – some of the studies we considered to provide weaker forms of evidence of change (e.g. assumed increase in knowledge based purely on participation rates claimed by study authors, who tended to be the designers and implementers of the same courses of which they were purporting the success), while others we considered to be stronger, albeit still based on testimonial or self-perception evidence (e.g. pre- and post- questionnaires or student surveys, after a curricular or pedagogical intervention). The scope and scale of measurement would also affect the strength of the evidence: for example, some studies only provided testimonial evidence of change associated with the experience of one teacher in one project or activity. It was not possible to depict this level of detail within the model represented by Figure 4 because not all articles included the information in the methodology sections of their work.

The second caveat in interpreting this model is that it effaces the differences between forms of change; while most articles discussed changes which sought to address the climate crisis, in the public debate modality three articles established changes which conversely restricted people’s capacity to respond to/take action in support of climate justice. Two of these highlighted the negative impact of conservative legal frameworks on university faculty, hampering academics’ work and constraining climate action (Ley 2018; Polsky 2019), while a third highlighted that enhanced knowledge of the crisis through increased media was associated with negative, pessimistic attitudes and poor mental health impacts amongst students (El Zoghbi and El Ansari 2014).

The third caveat in interpreting this model is that there were no articles synthesised in the knowledge production function of the university that themselves offered evidence of change. In Figure 4 (below), therefore, the knowledge production function double counts articles also included in the community engagement function of the university, highlighting that five articles focused on the dissemination and co-production of research with practitioners and policy-makers sat neatly across these two modalities (Addor et al. 2015; Lane et al. 2013; Hillmer-Pegram et al. 2012; Taylor et al. 2016; Wesselink and Gouldson 2014). For this reason, the modality is shaded grey in Figure 4 below.

Figure 4. University responses to the climate crisis: documenting change



From Figure 4 we can draw out some implications for the body of literature as a whole. Certain forms of change are better documented than others, with a predominance of studies showing changes in knowledge and attitudes, and only a small number documenting changes in infrastructure and emissions. There are various possible explanations for this emphasis: it may represent a skew in the activities of universities, but equally it might be attributed to the preferences of researchers and the ease of collecting data. Teasing out the differences requires close-up assessment in context.

The total number of studies in each modality of course reflects the distribution of published research as a whole. However, the balance of types of change within each of the modalities is revealing. One would expect certain modalities to be linked to certain kinds of change: so education to be connected with changes in knowledge and attitudes, and campus sustainability to changes in infrastructure. However, all of the modalities are linked to both internal and external change: educational interventions are also connected with societal transformation, and campus sustainability and governance initiatives are also connected with shifts in knowledge and attitudes. This is an important finding as these kinds of cross-linkages are vital given the complex and interlocking nature of the climate crisis. Nevertheless, there are some differences of distribution. The education modality studies are weighted towards epistemic and ethical change, as would be expected. All of the studies providing evidence of emissions and infrastructure change stem from the community engagement and campus operations modalities.

All typologies and categorisations entail a degree of simplification of phenomena, and in this case the forms of impact are less insulated and more interdependent than the categories suggest. However, if we bear this nuance in mind, the typology can be useful in orienting our research and practice. The challenge of climate change is one that encompasses diverse dimensions of the human being and sectors of society: internally it requires knowledge and understanding, but also shifts in values and behaviour; externally, it requires a transformation of structures and practices. Attention to these diverse forms of impact of the university is, therefore, important.

In mapping the various kinds of impact by modality, as in Figure 4, we also start to see the emphases of the different activities of HEIs, and can begin to balance their range of actions. In this, we need to be mindful that the figures above referred to published literature on university practice, rather than the practice itself, as will be explored further in the conclusion that follows.

8.0 Conclusion

The purpose of this systematic review is not to present a definitive claim about the practice of universities worldwide in response to climate change (a task that would require collection of new primary data). Instead, it presents the view of practice provided through the window of published research literature in established international journals. This view is coloured by a series of factors: the interests of researchers, the boundaries of what are seen to constitute valid and significant research studies, and the acceptance of articles in highly selective journals. From this body of literature we can draw a number of conclusions about what is there, but we must be cautious on commenting on what is not. As the saying goes, absence of evidence is not evidence of absence. The fact that there are few studies documenting influence of academics on public conceptions of climate change through social media does not mean that such influence does not exist, only that it has not yet been researched and published between 1990 and June 2020 in the journals collated by the Web of Science reviewed for this report.

Even in relation to the total global body of literature, the Web of Science collection specifically provides a number of skews. Given the high rates of rejection of these journals, output of established researchers in well-resourced universities is privileged. Most of the journals are in the English language, and while initially considering multilingual review, ultimately this analysis was restricted to English-language studies. While there are cases of researchers focusing on contexts other than their own, the above two points also lead to a predominance of analyses of high-income Anglophone contexts. It is highly important, therefore, not to draw the conclusion from this review that little action is being taken in relation to the climate emergency in universities in the Global South or in non-Anglophone contexts. Other research conducted as part of the Climate-U project shows clearly that this is not the case.

With these caveats in mind, there are some highly important findings that this review can put forward. First, there is extensive evidence that higher education institutions are taking action in relation to the climate emergency across the diverse functions of education, knowledge production, community engagement, public debate and campus sustainability. These efforts should be celebrated, while not losing sight of the negative impacts that higher education also has through its own emissions (Shields 2019; Davies & Dunk 2015) and the more that can and needs to be done in relation to mitigation, adaptation and regeneration. Second, the review presents evidence and in-depth analyses of the effectiveness of these interventions, and the factors that can support or hinder it. While 13 of the 151 included studies analysed only surveyed the field (documenting practice), and 62 identified pathways to impact, 76 of the studies assessed the evidence supporting this impact. Drawing these analyses together, this review puts forward a framework for distinguishing different forms of climate-relevant impact, namely: epistemic, ethical, behavioural, institutional, structural and atmospheric. As seen in the previous section, there are some intriguing configurations

of these impacts in relation to the different activities of the university. This framework can support future efforts to better understand and map the diverse influences of the university on climate change.

A third important area of contribution of this review is to understand the research field itself. The distribution of studies tells us much about the priorities of researchers in relation to climate change and higher education, and about the possibilities of 'measurement' and attribution. Generally speaking, there is a significant challenge in gauging universities' impact on climate change as only some of the influences are amenable to observation and documentation in the short term (McCowan 2022). CO₂ emissions and immediate learning outcomes of a module, for example, are amenable to research; there are much greater difficulties in assessing indirect impacts that are more dispersed and with a longer timeframe, say, the benefits of incorporation of sustainability principles into engineering courses through the work of graduates, or a student-led awareness-raising campaign via radio.

Furthermore, there are important interactions between the different modalities: this review has highlighted that few of the studies consider more than one modality simultaneously nor consider the effects they have on each other. In addition, most of the studies included in the review focus on 'outcomes' – that is to say the immediately apparent results of an activity, rather than the more demanding task of gauging 'impact' (in the sense of acknowledging the counterfactual, or what would have happened if the intervention had not taken place). There are also skews in the research field stemming from convenience: many studies of teaching focus on courses researchers themselves have taught, and on other activities taking place within the institutions of the researchers. While researchers may be able to critique their own practice and institutions, there are benefits to the body of evidence to including outsider as well as insider research. While all bodies of literature have limitations of this type, it is important to raise awareness of the skews that exist so as to temper our resulting inferences about practice, and in order to orient our future research practices.

In relation to the research field, there are also some noticeable patterns in terms of publication outlet. Journals in the field of education are surprisingly poorly represented. No articles were picked up for the review from publications in international and comparative education, and few from the large field of higher education studies. The slow uptake of educational researchers around issues of climate, and specifically in higher education, needs to be addressed. A clear finding of the review is the marked rise in the volume of articles generally speaking, moving from a single publication in 2003, to over 10 a year in the period 2014-2016 and then to over 20 a year between 2017-2019, showing the clear increase in interest in this topic amongst researchers. This is a positive trend in generating the body of evidence needed to support effective practice.

There are number of areas that emerge from this review as being in need of further research. Climate change is necessarily a value-based issue, raising as it does questions of justice, freedom and the good life. Much greater understanding is needed in understanding the complex role that values play in education, research and campus life, and how values are shaped through these processes. Furthermore, it is noticeable that climate justice is largely invisible in this body of literature. While the moral responsibility of the university to act in response to the crisis was mentioned in some articles, it was rarely linked to questions of global justice around inequalities, coloniality and disproportionate responsibilities and impacts in the climate crisis. The synthesis raises questions such as – what kind of ethical considerations have a role in evaluating evidence of impact in studies involving Global South-North university collaborations? What is the place of researchers' self-reflexivity in establishing methodological rigour for evidence of university response to climate change? How could consistency and coherence in impact of universities be understood such that contextual diversity in the global university response is explored meaningfully, and fostered? Answering these questions would have implications not only for the immediate academic stage of impact of university response, but also for the other three stages viz. bridging actors, society, and ecosphere (McCowan 2020).

Finally, the review raises questions for the nature of the institution. In posing the question of how universities are responding to the crisis, we inevitably must address the question of who or what is responding. Agency in universities is a complex thing, given the multiple actors and complex lines of management, complicated further by principles of academic freedom and traditions of autonomy that act against central control. While coherence may be desirable, the effectiveness of universities' responses to the climate emergency may in fact not be dependent on complete coordination, and a certain degree of messiness may be possible or even positive in terms of generating creative responses. Understanding that complex patchwork within institutions and between them, both nationally and globally, is the task facing researchers in the years that come in supporting their response to the social and environmental emergency facing the planet.



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10.0 Appendices

10.1 Appendix 1: Search terms

The following Boolean search terms were entered into the Web of Science, Scopus and Eric databases (with peer-reviewed articles as a filter). Language filters for articles published in English, French, Portuguese and Spanish were used.

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((TITLE("higher education" AND "climate change") OR ABS("higher education" AND "climate change")) OR ((TITLE("higher education" AND "global warming") OR ABS("higher education" AND "global warming"))) OR ((TITLE("university*" AND "climate change") OR ABS("university*" AND "climate change"))) OR ((TITLE("university*" AND "global warming") OR ABS("university*" AND "global warming"))) OR ((TITLE("tertiary education" AND "climate change") OR ABS("tertiary education" AND "climate change"))) OR ((TITLE("tertiary education" AND "global warming") OR ABS("tertiary education" AND "global warming"))) OR ((TITLE("campus" AND "global warming") OR ABS("campus" AND "global warming"))) OR ((TITLE("campus" AND "climate change") OR ABS("campus" AND "climate change"))))
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10.2 Appendix 2: Systemic Review Website Searches

Nine websites which house systematic reviews were searched in English, using the following search terms (as defined above in Appendix 1): *university** OR "higher education" OR "tertiary education" OR "campus" AND "climate change"

The results from this searching are included in the table below. Where these websites yielded relevant systematic reviews, these were integrated into the literature review included in part 3 of this paper.

Title & hyperlink for website	Results
1. 3ie: https://developmentevidence.3ieimpact.org/	18 titles screened
2. Campbell Systematic Reviews: https://onlinelibrary.wiley.com/journal/18911803	63 titles screened
3. Prospero: http://www.crd.york.ac.uk/prospero/	47 titles screened
4. York Centre for Reviews and Dissemination (Public health focused): www.york.ac.uk/crd/	0 results found
5. Cochrane library: www.cochranelibrary.com/	6 titles screened
6. Collaboration for Environmental Evidence: www.environmentalevidence.org/	0 results found
7. www.epistemonikos.org/	4 titles screened
8. www.eppi.ioe.ac.uk	6 systematic review topics on higher or further education screened
9. https://systematicreviewsjournal.biomedcentral.com/articles	4 systematic reviews on climate change screened

10.3 Appendix 3: Journal of publication (included studies)

Journal of publication	Number of studies
International Journal of Sustainability in Higher Education	18
Journal of Cleaner Production	12
Sustainability	10
Climatic Change	4
Journal of Chemical Education	3
Local Environment	3
Australian Journal of Environmental Education	2
Bulletin of the American Meteorological Society	2
Ecology and Evolution	2
HortTechnology	2
International Journal of Climate Change Strategies and Management	2
International Journal of Global Warming	2
Journal of Contemporary Water Research & Education	2
Journal of Environmental Psychology	2
Journal of Extension	2
Law and Policy	2
Nurse Education Today	2
Weather, Climate, and Society	2
Acta Sociologica	1
Action Learning: Research and Practice	1
Advances in Energy Research	1
Applied Geography	1
ARCTIC	1
Australian Journal of Management	1
Australian Journal of Public Administration	1
Australian Social Work	1
BioScience	1
Bothalia	1
Canadian Journal of Higher Education	1
Canadian Journal of Sociology	1
Carbon Management	1
Central European Journal of Public Health	1
Coastal Management	1
Creative Nursing	1
Critical Sociology	1
Earth's Future	1
Ecological Engineering	1
Ecology and Society	1
Educ. Sci.	1
Elementa: Science of the Anthropocene	1
Energy Policy	1
Environment and Urbanization	1
Environmental Communication	1
Frontiers in Ecology and the Environment	1
Frontiers of Architectural Research	1
Frontiers of Engineering Management	1



GAIA - Ecological Perspectives for Science and Society	1
Global Environmental Politics	1
Higher Education Research and Development	1
Information, Communication and Society	1
International Forestry Review	1
International Journal of Educational Technology in Higher Education	1
International Journal of Entrepreneurial Venturing	1
International Journal of Environmental Research and Public Health	1
International Journal of Urban and Regional Research	1
International Nursing Review	1
International Review of Education	1
International Studies Perspectives	1
Journal of Curriculum Studies	1
Journal of Energy and Natural Resources Law	1
Journal of Environmental Science and Management	1
Journal of Forestry	1
Journal of Geography in Higher Education	1
Journal of Green Building	1
Journal of Industrial Relations	1
Journal of Science Teacher Education	1
Journal of Sustainable Tourism	1
Journal of Urban Management	1
Marine Policy	1
McGill Journal of Education	1
Ocean and Coastal Management	1
PLoS ONE	1
Policy and Practice: A Development Education Review	1
Policy Sciences	1
Polish Journal of Environmental Studies	1
Renewable and Sustainable Energy Reviews	1
Research in Science & Technological Education	1
SAGE Open	1
Science Communication	1
Simulation and Gaming	1
SSRN Electronic Journal	1
Sustainability Science	1
Sustainable Cities and Society	1
Teaching in Higher Education	1
TECHNE - Journal of Technology for Architecture and Environment	1
The Canadian Geographer	1
The Design Journal	1
The International Journal of Management Education	1
The International Review of Research in Open and Distributed Learning	1
The Law Teacher	1
The Professional Geographer	1
UCLA Law Review	1
Water	1
Wildlife Society Bulletin	1
Wiley Interdisciplinary Reviews: Climate Change	1

10.4 Appendix 4: Studies providing evidence of change (by modality)

Reference	Modality	Country of focus	Methodology	Type of impact
(Burandt and Barth 2010)	Education – Curriculum	Germany	Qualitative: Qualitative analysis of survey data	Development of generic competencies related to collaboration, interdisciplinary work on complex, real-life world problems, and self-directed learning.
(Cantalapiedra, Bosch, and Lopez 2006)	Education - Curriculum	Spain	Qualitative: Qualitative analysis of survey data	Improvement in students' knowledge and aptitude about environmental issues, and effect on students' sensitivity and attitudes towards environmental issues.
(Coelho et al. 2015)	Education - Curriculum	Portugal	Quantitative: quantitative analysis of survey data	Impact on student's knowledge measured by extent of student activity on the online platforms related to the MOOC, and course completion rate.
(Duffy, Hammond, and Cheng 2019)	Education - Curriculum	USA	Quantitative: pre- and post-questionnaire, quantitative analysis of survey data	Change in students' understanding and beliefs about climate change, their attitudes towards climate change and their beliefs in efficacy of taking action , whether individually or collectively
(Ferreira et al. 2012)	Education - Curriculum	Multi-country: Brazil, Russia, India, China, Mexico	Mixed methods: pre- and post- questionnaire, quantitative and qualitative analysis of survey data	Improvements in awareness about global warming, self-efficacy belief about personal action for mitigating climate change, and understanding of governmental policies on climate change for countries represented in the cohort.
(Krütli, Pohl, and Stauffacher 2018)	Education - Curriculum	Seychelles	Qualitative: informal consultations & reflection, participatory methods	Improvement in students' learning of general scientific skills and competencies .
(Lavey 2019)	Education - Curriculum	USA	Qualitative: Case study, informal consultations & reflection	Enhancement in students' knowledge (measured by proxy through students' engagement with the activities or assignments of the programme)
(Mahaffy et al. 2017)	Education - Curriculum	Multi-country: (USA and Canada)	Mixed methods: pre- and post-questionnaire, documentary analysis, statistical analysis	Gains in student understanding of chemistry underlying climate change and knowledge of sustainability science literacy.
(Monroe, Ireland, and Martin 2015)	Education - Curriculum	USA	Mixed methods: quantitative and qualitative analysis of survey data, informal	Enhanced learning about climate change mitigation and adaptation related to southern pine forests. Development of understanding of interdisciplinary research, online and distance learning, and connection between research and extension.
(Otto et al. 2019)	Education - Curriculum	Multi-country (Germany and Portugal)	Quantitative: quantitative analysis of survey data	Students' self-perception of improvement in their knowledge and competencies related to climate change, and awareness of the social justice dimension of the climate change.
(Smith, Banet, and Martinez Romera 2019)	Education - Curriculum	Multi-country (Denmark, Norway, US)	Qualitative: informal consultations & reflection, qualitative analysis of survey data	Testimonial evidence from students (student feedback) pointing to benefits owing to the cross-contextual, collaborative nature of the programme. Knowledge production by students in the form of a paper written by a team of students which was slated to be published in a peer-reviewed journal.
(Stupar, Mihajlov, and Simic 2017)	Education - Curriculum	Serbia	Quantitative: Pre- and post-questionnaire, statistical analysis	Improvement in students' awareness and knowledge about climate change.
(Wasco 2019)	Education - Curriculum	USA	Qualitative: informal consultations & reflection	Testimonial evidence from students (student feedback) pointing to increased awareness of health-related effects of climate change.



(Hanrahan and Shafer 2019)	Education - Curriculum	USA	Mixed methods: quantitative and qualitative analysis of survey data	Enhancement in students' interest in climate change in terms of increased interest in future career paths related to climate change, and enhanced sense of responsibility and willingness for engaging in public outreach activities on climate change.
(Nam and Ito 2011)	Education - Curriculum	USA	Mixed methods: quantitative analysis of survey data, participant-observations, interviews	Enhancement of students' understanding, skills and attitudes about historic interaction between human society and climate, and improvement in competencies related to science of climate change. Measured behaviour but found only small evidence of change.
(Cordero, Centeno, and Todd 2020)	Education - Curriculum	USA	Mixed methods: interviews, quantitative and qualitative analysis of survey data	Long-term change in student behaviour related to their personal carbon footprint.
(Hay and Eagle 2020)	Education - Curriculum	Australia	Quantitative: quantitative analysis of survey data	Increased awareness of climate change, enhanced understanding of contributors to climate change, and enhanced sense of collective social and governmental responsibility to mitigate climate change. Students reported changing behaviours , e.g., saving water or switching off lights.
(Booth, Aben, et al. 2020)	Education - Pedagogy	Canada	Qualitative: informal consultations & reflection	Action learning and real-world application led to student knowledge and understanding and attitudes
(Bowser et al. 2014)	Education - Pedagogy	USA	Quantitative: quantitative analysis of survey data	Interdisciplinary and place-based learning led to student knowledge and understanding
(Burch and Harris 2014)	Education - Pedagogy	Canada	Quantitative: quantitative analysis of survey data	Collaborative online learning (MOOC) led to student knowledge and understanding and attitudes
(Bush et al. 2019)	Education - Pedagogy	Multi-country (primarily USA, Canada and Europe, some from Asia and Global South)	Quantitative: quantitative analysis of survey data	Teacher's provide testimonial evidence of change to student knowledge and understanding after using satellite and spatial mapping tools in teaching geographical process of anthropogenic global climate change.
(Correia et al. 2010)	Education - Pedagogy	Brazil	Mixed methods: participatory methods, documentary analysis, quantitative analysis of survey data	Expressing understanding of climate change using concept maps (Cmaps) impacts student knowledge and understanding
(Davidson et al. 2014)	Education - Pedagogy	Australia	Qualitative: participatory methods	Interdisciplinary and distributed leadership partnerships between universities led to teachers' knowledge and understanding
(de Gaulmy and Dupre 2019)	Education - Pedagogy	Australia	Mixed methods: quantitative and qualitative analysis of survey data	Sustainable performance simulation tool when used in groups impacts architecture students' knowledge and understanding of sustainable design
(Dittmer et al. 2018)	Education - Pedagogy	Multi-country (Uganda and Germany)	Qualitative: interviews	Action-oriented education programme led to increased student knowledge and understanding and developed action competencies
(Doran 2016)	Education - Pedagogy	UK	Qualitative: qualitative analysis of survey data, participatory methods	Web-based simulation tool which allows for experiential learning led to student-reported gains in knowledge and understanding and shift in attitudes
(Joyner Armstrong et al. 2016)	Education - Pedagogy	USA	Qualitative: interviews	Analysis of holistic, sustainability-infused curricula across university led to growth in student knowledge and understanding and shift in attitudes
(Lysack 2009)	Education - Pedagogy	Canada	Qualitative: informal consultations & reflection	A teach-in event on global warming contributed to participant (aged teen to 70+) knowledge and understanding and shifts in attitude

(Matzner and Herrenbrück 2016)	Education - Pedagogy	Germany	Qualitative: informal consultations & reflection, participatory methods	Collaborative activity which simulates international scenarios of negotiation was valuable according to students and teachers; testimonial evidence of impact to knowledge and understanding
(Micklethwaite and Knifton 2017)	Education - Pedagogy	UK	Qualitative: Participatory methods, informal consultations & reflection	Participation in a pop-up studio as a method of public engagement on climate change impacted students' knowledge and understanding and attitudes
(Morrison et al. 2020)	Education - Pedagogy	USA	Mixed methods: informal consultations & reflection, quantitative analysis of survey data	In-class dialogue increases student capacities for learning about climate change (i.e., knowledge and understanding), most especially for non-science majors
(Otto 2017)	Education - Pedagogy	Multi-country (UK, Germany, Spain, Portugal, Belgium, Netherlands)	Qualitative: storytelling, informal consultations & reflection	Digital storytelling technology across borders impacts students' knowledge and understanding and attitudes
(Perry and Thompson 2019)	Education - Pedagogy	USA	Mixed methods: pre- and post- questionnaire, qualitative analysis of survey data	Interactive course introducing a new capacity tool for watershed managers led to students' metacognitive (self-assessed) gains to knowledge and understanding
(Pettenger, West, and Young 2014)	Education - Pedagogy	Multi-country (USA and Canada)	Mixed methods: pre- and post- questionnaire, participant-observations, informal consultations & reflection	Role play simulation for students of international relations and politics led to growth in knowledge and understanding
(Pharo et al. 2012)	Education - Pedagogy	Australia	Qualitative: documentary analysis, informal consultations & reflection	Interdisciplinary teaching network led to systematic and structural changes to teaching and learning
(Pharo et al. 2014)	Education - Pedagogy	Australia	Mixed methods: interviews, informal consultations & reflection	Establishing informal connections between different universities (or 'communities of practice') contributed to systematic and structural changes to teaching and learning
(Radaković et al. 2017)	Education - Pedagogy	Serbia	Quantitative: quantitative analysis of survey data	Students who participated in organised academic environmental activities (re: climate change) demonstrated changes in knowledge and understanding and attitudes towards learning more about the topic
(Richardson et al. 2017)	Education - Pedagogy	UK	Quantitative: pre- and post-questionnaire, quantitative analysis of survey data	Changes to nursing and midwifery student knowledge and understanding and attitudes following introduction of scenario-based learning
(Selin 2016)	Education - Pedagogy	Multi-country (primarily USA, some European)	Qualitative: informal consultations & reflection, quantitative analysis of survey data, interviews	Teachers' testimonial evidence of change to student knowledge and understanding and attitudes after incorporating environmental summits into interdisciplinary educational practice
(Sloane and Wiles 2020)	Education - Pedagogy	USA	Mixed methods: pre- and post- questionnaire, quantitative and qualitative analysis of survey data	Engaging with scholarly literature on climate change impacts student knowledge and understanding and attitudes
(Theobald et al. 2015)	Education - Pedagogy	USA	Quantitative: pre- and post-questionnaire	Learning the biological consequences of climate change in the local and global contexts impact student knowledge and understanding and attitudes
(Tomas et al. 2019)	Education - Pedagogy	Australia	Mixed methods: informal consultations & reflection, quantitative and qualitative analysis of survey data	A 'flipped' learning model with appropriate degrees of teacher-led instruction positively impacts student knowledge and understanding
(Jay et al. 2019)	Education - Pedagogy	USA	Quantitative: pre- and post-questionnaire, quantitative analysis of survey data	A food-based environmental science course impacted carbon footprint of student food choices (based on self-reported dietary changes): behavioural change



(Hestness et al. 2017)	Education - Teacher Education	USA	Qualitative: interviews, participant-observations, participatory methods	Use of learning progressions (LPs) concept aids existing educators' (at various levels of basic and higher education) knowledge and understanding
(Namdar 2018)	Education - Teacher Education	Turkey	Mixed methods: quantitative and qualitative analysis of survey data	Inquiry-based learning led to teacher preparedness (knowledge and understanding)
(Richter-Beuschel, Grass, and Bögeholz 2018)	Education - Teacher Education	Germany	Mixed methods: quantitative and qualitative analysis of survey data	Differentiates between types of trainee knowledge necessary for developing Sustainable Development (SD) competencies, impacting knowledge and understanding
(Richter-Beuschel and Bögeholz 2019)	Education - Teacher Education	Germany	Quantitative: quantitative analysis of survey data	Found low procedural knowledge amongst student teachers regarding biodiversity loss and climate change
(Franta 2017)	Public debate	USA	Qualitative: documentary analysis	Student lawsuit against Harvard University to compel fossil fuel divestment enhanced awareness of crisis, and reframed in attitudes as moral (rather than technical) responsibility; litigation itself a student-led systemic climate action
(Grady-Benson and Sarathy 2015)	Public debate	USA	Qualitative: participant-observations, documentary analysis, qualitative analysis of survey data	Student led FFD campaigns raising awareness , supporting individual and institutional values of social justice, self-efficacy beliefs and collective action
(Healy and Debski 2016)	Public debate	USA	Qualitative: participant-observation, documentary analysis, interviews	Student-led FFD campaigns raising awareness and supporting shifts in attitudes from technocratic perspectives to morally-infused systemic & socio-economic change, linked with justice concerns. Collective action by students (in some cases with faculty) leading to some institutional policy changes (but caveat that not universal)
(Helferty and Clarke 2009)	Public debate	Canada	Mixed methods: quantitative analysis of survey data, informal consultations & reflection	Identification of categories of student-led climate change actions on campus, documented student-led awareness raising campaigns and long-term policy development, positive attitudes assessed through student participation / levels of youth engagement
(Maina, Murray, and McKenzie 2020)	Public debate	Canada	Qualitative: documentary analysis	Student-led fossil fuel divestment campaigns leading to an upward trend in HEI policy-based changes , social media found as a key site for raising awareness in collaborative student actions ; evidence of beliefs around solidarity with Indigenous movements, and internal student movements influencing alumni attitudes
(El Zoghbi and El Ansari 2014)	Public debate	South Africa	Qualitative: interviews, participant-observations	Broad socio-political context (media) and presentation of pessimistic (albeit enhanced) understanding of crisis shown to have negative impact on student attitudes & well-being
(Ley 2018)	Public debate	USA	Qualitative: interviews	Broad socio-political context (conservative legal frameworks) shown to have negative impact on academic attitudes through reported disengagement of faculty
(Polsky 2019)	Public debate	USA	Qualitative: documentary analysis	Broad socio-political context (conservative legal frameworks) shown to have negative impact on academic attitudes through reported disengagement of faculty
(Asherman et al. 2016)	Community engagement	France	Quantitative: quantitative analysis of survey data	Visually simple and hands on experiments both stimulated student interest in science while improving awareness of the challenges of climate change

(Monroe and Oxarart 2019)	Community engagement	USA	Mixed methods: pre- and post- questionnaire, quantitative analysis of survey data	Integrated research, cooperative extension and education increased educator confidence, knowledge gain amongst biology and environmental science secondary school students, increased student engagement and increased student skills in systems thinking and application of science
(Booth, Earley, et al. 2020)	Community engagement	Canada	Qualitative: informal consultations & reflection	Partnership between city and university supporting development of carbon action plans and measurement of carbon neutrality, gains in knowledge in both community and student participants, student autonomy and actions
(Pacheco et al. 2019)	Community engagement	Spain	Qualitative: informal consultations & reflection	Engineering students in Spain gaining knowledge, skills, social engagement and employability through real world pedagogies and contributing to action and emissions reductions (installation of a wind turbine)
(Parker, Rowlands, and Scott 2003)	Community engagement	Canada	Mixed methods: assessment of emissions, quantitative analysis of survey data	Actions to reduce residential energy use and carbon emissions through partnership with local university as trusted stakeholder; raising public awareness and providing training and skills to students
(Whitehouse et al. 2017)	Community Engagement	Australia	Qualitative: qualitative analysis of survey data	Experiential learning leading to increased knowledge , shifting attitudes to climate & relationship with nature
(Addor et al. 2015)	Community engagement	Switzerland	Qualitative: qualitative analysis of survey data, participatory methods	Workshop enhanced participants' knowledge of uncertainty, and shifted attitudes to the process of engagement between academia and decision-makers
(Lane et al. 2013)	Community engagement	Multi-country (Canada + Caribbean)	Mixed methods: interviews, GIS/GPS mapping/modelling, quantitative analysis of survey data	Increase in local and student awareness , development of community action plans
(Hillmer-Pegram et al. 2012)	Community engagement	USA	Mixed methods: assessment of emissions, interviews	Case study of university-generated emissions inventory used to support regional mitigation planning process, enhancing local knowledge , supporting environmental activism and challenging climate sceptic attitudes
(Taylor et al. 2016)	Community engagement	South Africa	Mixed methods: quantitative analysis of survey data, informal consultations & reflection, interviews	Research programme between university and local municipality built collaborative capacity and enhanced stakeholder and student knowledge; shifts in attitudes around value of process of knowledge exchange on policy
(Wesseling and Gouldson 2014)	Community engagement	UK	Qualitative: interviews	Co-produced policy work led to enhanced local municipality "usable knowledge " and advocacy
(Ahn and Schmidt 2019)	Community engagement	USA	Quantitative: assessment of water flow	Urban wetland infrastructure raised student and community awareness of sustainable stormwater management
(P. S. Hart, Stedman, and McComas 2015)	Community engagement	USA	Quantitative: quantitative (psychometric) analysis of survey data	Psychological analysis found that public attitudes towards university mitigation efforts did not vary by proximity but by type of proposal
(Marcell, Agyeman, and Rappaport 2004)	Campus operations	USA	Mixed methods: quantitative analysis of survey data, interviews	Small-scale pilot study to reduce GHG emissions led to a positive impact on student environmental knowledge, attitudes, and behaviours but not statistically significant emissions reductions
(Waliczek, McFarland, and Holmes 2016)	Campus operations	USA	Quantitative: quantitative analysis of survey data	Surveys showed positive environmental attitudes and increased knowledge amongst students at the campus with an active composting programme
(Adewole, Agbola, and Kasim 2015)	Campus operations	Nigeria	Mixed methods: interviews, participant-observations, GIS/GPS mapping	Effective infrastructure adaptations were taken at a university campus to build resilience and reduce vulnerability



(Hoyo-Montaño et al. 2019)	Campus operations	Mexico	Mixed methods: informal consultations & reflection, assessment of emissions	Results from a pilot energy saving program on campus showed effective infrastructure adaptations in terms of energy saving and financial payback
(Mazhar, Bull, and Lemon 2017)	Campus operations	UK	Qualitative: documentary analysis, interviews	Content analysis and interviews put forward critical success factors (e.g., leadership, funding or stakeholder engagement) that can contribute to effective infrastructure adaptations within HEIs
(Pollard 2016)	Campus operations	USA	Mixed methods: documentary analysis, quantitative and qualitative analysis of survey data	Analysis of improvements to energy usage through a survey and content analysis: emissions reductions (associated with effective infrastructure adaptation)
(Senbel, Ngo, and Blair 2014)	Campus operations	Canada	Mixed methods: pre- and post- questionnaire, interviews	A student competition was effective in achieving energy reduction and for shifts in student attitudes in terms of energy usage
(Evans and Karvonen 2014)	Campus operations	UK	Qualitative: interviews, documentary analysis, participant-observations	Strategic capital investments and partnerships with universities and local government responding to city-region target leading to policy-based changes

10.5 Appendix 5: Thematic coding summary (included studies)

Where articles include more than one modality as their focus, the dominant theme (i.e., the section of the synthesis in which these articles are discussed) is shown in bold text.

Reference	Country of focus	Methodology	Focus of study: higher education modality				
			Education	Knowledge production	Public debate	Community engagement	Campus operations
(Abbott and Kasprzyk 2012)	USA	Mixed methods: documentary analysis, rating & indexing					X
(Addor et al. 2015)	Switzerland	Qualitative: qualitative analysis of survey data, participatory methods				X	
(Adewole, Agbola and Kasim, 2015)	Nigeria	Mixed methods: interviews, participant-observations, GIS/GPS mapping					X
(Adom̄ent, Grahl, and Spira 2019)	Multi-country (Europe)	Mixed methods: interviews, pre- and post- questionnaires					X
(Ahn and Schmidt 2019)	USA	Quantitative: assessment of water flow				X	X
(Álvarez-Nieto et al. 2018)	Multi-country (Europe)	Mixed methods: quantitative analysis of survey data, qualitative analysis of survey data	X				
(Arevalo, Pitkänen, and Kirongo 2014)	Multi-country (Kenya & Finland)	Mixed methods: documentary analysis, quantitative analysis of survey data	X				
(Asherman et al. 2016)	France	Quantitative: quantitative analysis of survey data	X			X	
(Atherton and Giurco 2011)	Australia	Mixed methods: quantitative analysis of survey data, staff & student consultations					X
(Baer and Gallois 2018)	Australia	Qualitative: participant-observations					X
(Batisani and Ndiane 2014)	Botswana	Quantitative: assessment of emissions					X
(Berger, Gerum, and Moon 2015)	Canada	Mixed methods: interviews, quantitative analysis of survey data	X				
(Boddy, Macfarlane, and Greenslade 2018)	Australia	Qualitative: documentary analysis	X				
(Boeri et al. 2018)	Italy	Qualitative: participatory methods				X	
(Booth, Aben, et al. 2020)	Canada	Qualitative: informal consultations & reflection	X			X	
(Booth, Earley, et al. 2020)	Canada	Qualitative: informal consultations & reflection	X			X	
(Bothun 2016)	Multi-country (USA + Association African Universities)	Qualitative: documentary analysis, interviews	X			X	
(Bowser et al. 2014)	USA	Quantitative: quantitative analysis of survey data	X			X	
(Brugger and Crimmins 2015)	USA	Qualitative: interviews (organisational ethnography)				X	
(Burandt and Barth 2010)	Germany	Qualitative: qualitative analysis of survey data	X				
(Burch and Harris, 2014)	Canada	Quantitative: quantitative analysis of survey data	X				
(Bush et al., 2019)	Multi-country (primarily USA, Canada and Europe, some from Asia and Global South)	Quantitative: quantitative analysis of survey data	X				
(Cantalapiedra, Bosch, and Lopez 2006)	Spain	Qualitative: qualitative analysis of survey data	X				



(Coelho et al. 2015)	Portugal	Quantitative: quantitative analysis of survey data	X				
(Coffman 2009)	USA	Qualitative: documentary analysis					X
(Compagnucci and Spigarelli 2018)	Spain	Qualitative: interviews, documentary analysis, qualitative analysis of survey data				X	
(Cone et al. 2013)	USA	Qualitative: interviews, qualitative analysis of survey data, informal consultations & reflection				X	
(Cordero, Centeno, and Todd 2020)	USA	Mixed methods: interviews, quantitative and qualitative analysis of survey data	X		X	X	
(Coronacion 2015)	Philippines	Mixed methods: quantitative analysis of survey data, informal consultations & reflection	X				
(Correia, et al., 2010)	Brazil	Mixed methods: participatory methods, documentary analysis, quantitative analysis of survey data	X				
(Crow-Miller et al. 2016)	USA	Qualitative: informal consultations & reflection, interviews				X	
(Cruz, Alshammari, and Felicilda-Reynaldo 2018)	Saudi Arabia	Quantitative: quantitative analysis of survey data	X				
(Czerniewicz, Goodier, and Morrell 2017)	South Africa	Mixed methods: quantitative analysis of survey data, informal consultations & reflection		X			
(Davison, et al., 2014)	Australia	Qualitative: participatory methods	X			X	
(de Gaulmynn and Dupre, 2019)	Australia	Mixed methods: quantitative and qualitative analysis of survey data	X				
(Dent and Dalton, 2010)	UK	Mixed methods: quantitative and qualitative analysis of survey data	X				
(Dittmer, 2018)	Multi-country (Uganda and Germany)	Qualitative: interviews	X				
(Doll, Eschbach, and DeDecker 2018)	USA	Qualitative: informal consultations & reflection				X	
(Doran, 2016)	UK	Qualitative: qualitative analysis of survey data, participatory methods	X				
(Duffy, Hammond, and Cheng 2019)	USA	Quantitative: pre- and post-questionnaire, quantitative analysis of survey data	X				
(El Zoghbi and El Ansari 2014)	South Africa	Qualitative: interviews, participant-observations			X		
(Errett et al. 2019)	USA	Qualitative: qualitative analysis of survey data				X	
(Evans and Karvonen 2014)	UK	Qualitative: interviews, documentary analysis, participant-observations					X
(Fahey 2012)	Australia	Qualitative: documentary analysis	X				
(Ferreira et al. 2012)	Multi-country: Brazil, Russia, India, China, Mexico	Mixed methods: pre- and post-questionnaire, quantitative and qualitative analysis of survey data	X			X	
(Fillmore, Singletary, and Phillips 2018)	USA	Quantitative: quantitative analysis of survey data				X	
(Franta 2017)	USA	Qualitative: documentary analysis			X		
(Gamage and Sculli 2017)	Australia	Qualitative: documentary analysis					X
(García del Amo, Mortyn, and Reyes García 2020)	Spain	Mixed methods: quantitative analysis of survey data, literature review		X			
(Grady-Benson and Sarathy 2015)	USA	Qualitative: participant-observations, documentary analysis, qualitative analysis of survey data			X		
(Hanrahan and Shafer 2019)	USA	Mixed methods: quantitative and qualitative analysis of survey data	X			X	

(D. D. Hart et al. 2015)	USA	Qualitative: documentary analysis, interviews, participant-observations				X	
(P. S. Hart, Stedman, and McComas 2015)	USA	Quantitative: quantitative (psychometric) analysis of survey data				X	
(Hay and Eagle 2020)	Australia	Quantitative: quantitative analysis of survey data	X				
(Healy and Debski 2016)	USA	Qualitative: participant-observation, documentary analysis, interviews			X		
(Helferty and Clarke 2009)	Canada	Mixed methods: quantitative analysis of survey data, informal consultations & reflection			X		
(Henderson, Bieler, and McKenzie 2017)	Canada	Mixed methods: documentary analysis, quantitative analysis of survey data					X
(Hess and Collins 2018)	USA	Mixed methods: documentary analysis, quantitative analysis of survey data	X				
(Hestness et al., 2017)	USA	Qualitative: interviews, participant-observations, participatory methods	X				
(Hillmer-Pegram et al. 2012)	USA	Mixed methods: assessment of emissions, interviews				X	
(Hopkins et al. 2016)	New Zealand	Qualitative: documentary analysis					X
(Hoyo-Montaño et al. 2019)	Mexico	Mixed methods: informal consultations & reflection, assessment of emissions					X
(Inojosa, 2010)	Brazil	Mixed methods: quantitative analysis of survey data, informal consultations & reflection	X				
(Iwami et al. 2020)	Japan	Qualitative: documentary analysis				X	
(Jay et al., 2019)	USA	Quantitative: pre- and post-questionnaire, quantitative analysis of survey data	X				X
(Joyner Armstrong et al. 2016)	USA	Qualitative: interviews	X				
(Kayahan Karakul 2016)	Turkey	Qualitative: documentary analysis					X
(Kautto, Trundle, and McEvoy 2018)	Multi-country (45 institutions on 3 continents)	Quantitative: quantitative analysis of survey data					X
(Krütli, Pohl, and Stauffacher 2018)	Seychelles	Qualitative: informal consultations & reflection, participatory methods	X			X	X
(Kukkonen, Stoddart, and Ylä-Anttila 2020)	Multi-country (Finland & Canada)	Qualitative: documentary analysis			X	X	
(Lane et al. 2013)	Multi-country (Canada + Caribbean)	Mixed methods: interviews, GIS/GPS mapping/modelling, quantitative analysis of survey data				X	
(Lavey 2019)	USA	Qualitative: Case study, informal consultations & reflection	X				
(Leal Filho, Morgan, Godoy, Azeiteiro, Bacelar-Nicolau, Veiga Ávila, et al. 2018)	Multi-country: international (48 countries sampled)	Mixed methods: quantitative and qualitative analysis of survey data	X	X		X	
(Ledee et al. 2011)	USA	Qualitative: informal consultations & reflection				X	
(Lehtonen et al., 2018)	Finland	Qualitative: documentary analysis, informal consultations & reflection	X				
(Ley 2018)	USA	Qualitative: interviews			X		
(Linnenluecke et al. 2015)	Australia	Quantitative: rating & Indexing					X
(Liu et al. 2017)	China	Quantitative: assessment of ecological footprint, assessment of emissions					X
(Lohr 2014)	USA	Quantitative: Statistical analysis	X				
(Lysack, 2009)	Canada	Qualitative: informal consultations & reflection	X				
(Mahaffy, 2017)	Multi-country (USA and Canada)	Mixed methods: pre- and post-questionnaire, documentary analysis, statistical analysis	X				



(Maina, Murray, and McKenzie 2020)	Canada	Qualitative: documentary analysis					X
(Marcell, Agyeman, and Rappaport 2004)	USA	Mixed methods: quantitative analysis of survey data, interviews					X
(Markey and McIvor 2019)	Australia	Qualitative: documentary analysis				X	X
(Matzner and Herrenbrück, 2017)	Germany	Qualitative: informal consultations & reflection, participatory methods	X				
(Mazhar, Bull, and Lemon 2017)	UK	Qualitative: documentary analysis, interviews					X
(McCartney and Gray 2018)	Canada	Qualitative: documentary analysis					X
(McComas, Stedman, and Sol Hart 2011)	USA	Quantitative: quantitative analysis of survey data					X
(Micklethwaite and Knifton, 2017)	UK	Qualitative: Participatory methods, informal consultations & reflection	X				
(Mitsch et al. 2008)	Costa Rica	Mixed methods: participant-observations, informal consultations & reflection, assessment of emissions					X
(Molthan-Hill et al. 2019)	Multi-country	Mixed methods: quantitative and qualitative analysis of survey data	X				
(Molthan-Hill et al. 2020)	UK	Qualitative: documentary analysis, informal consultations & reflection					X
(Monroe, Ireland, and Martin 2015)	USA	Mixed methods: quantitative and qualitative analysis of survey data, informal consultations & reflection	X			X	X
(Monroe and Oxarart 2019)	USA	Mixed methods: pre- and post-questionnaire, quantitative analysis of survey data	X	X		X	
(Morrison, et al., 2020)	USA	Mixed methods: informal consultations & reflection, quantitative analysis of survey data	X				
(Mulvaney and Druschke 2017)	USA	Qualitative: interviews				X	
(Nagy et al. 2017)	Multi-country (Bolivia, Paraguay, Uruguay, Venezuela)	Qualitative: informal consultations & reflection	X	X		X	
(Nam and Ito 2011)	USA	Mixed methods: quantitative analysis of survey data, participant-observations, interviews	X				
(Namdar, 2018)	Turkey	Mixed methods: quantitative and qualitative analysis of survey data	X				
(Nicol et al., 2019)	UK	Qualitative: Case study, informal consultations & reflection Interviews	X				
(Nursey-Bray et al. 2019)	Australia	Mixed methods: interviews, quantitative analysis of survey data					X
(O'Keeffe 2016)	Ethiopia	Qualitative: interviews					X
(Otto, 2017)	Multi-country (UK, Germany, Spain, Portugal, Belgium, Netherlands)	Qualitative: storytelling, informal consultations & reflection	X				
(Otto et al. 2019)	Multi-country (Germany and Portugal)	Quantitative: quantitative analysis of survey data	X				
(Owen, Fisher, and McKenzie 2013)	Canada	Mixed methods: informal consultations & reflection, quantitative analysis of survey data					X
(Pacheco et al. 2019)	Spain	Qualitative: informal consultations & reflection	X			X	
(Parker, Rowlands, and Scott 2003)	Canada	Mixed methods: assessment of emissions, quantitative analysis of survey data	X	X	X	X	

(Pearson 2013)	Australia	Qualitative: documentary analysis	X				
(Pease, Chaney, and Hoover 2019)	USA	Qualitative: documentary analysis	X				
(Perkins, et al., 2018)	Multi-country (Brazil, China, Germany, Mexico, Saudi Arabia, USA)	Qualitative: qualitative analysis of survey data, interviews	X				
(Perales Jarillo et al. 2019)	Multi-country (Spain, Ecuador, Colombia, Mexico, and Peru)	Qualitative: informal consultations & reflection					X
(Perry and Thompson, 2019)	USA	Mixed methods: pre- and post-questionnaire, qualitative analysis of survey data	X				
(Pettenger, West and Young, 2014)	Multi-country (USA and Canada)	Mixed methods: pre- and post-questionnaire, participant-observations, informal consultations & reflection	X				
(Pharo et al., 2012)	Australia	Qualitative: documentary analysis, informal consultations & reflection	X				
(Pharo, et al., 2014)	Australia	Mixed methods: interviews, informal consultations & reflection	X			X	
(Pollard 2016)	USA	Mixed methods: documentary analysis, quantitative and qualitative analysis of survey data					X
(Polsky 2019)	USA	Qualitative: documentary analysis			X		
(Prokopy et al. 2015)	USA	Mixed methods: quantitative analysis of survey data, interviews				X	
(Raciti and Sajja 2018)	Multi-country (USA and Italy)	Qualitative: informal consultations & reflection, interviews, participatory methods	X			X	
(Radaković et al., 2017)	Serbia	Quantitative: quantitative analysis of survey data	X				
(Redfern and Zhong 2017)	Multi-country (UK and China)	Quantitative: quantitative analysis of survey data					X
(Reza, 2016)	Malaysia	Qualitative: documentary analysis	X				
(Richardson et al., 2017)	UK	Quantitative: pre- and post-questionnaire, quantitative analysis of survey data	X				
(Richter-Beuschel and Bøgeholz 2019)	Germany	Quantitative: quantitative analysis of survey data	X				
(Richter-Beuschel, Grass and Bøgeholz, 2018)	Germany	Mixed methods: quantitative and qualitative analysis of survey data	X				
(Rojas et al. 2017)	Chile	Quantitative: quantitative analysis of survey data	X				
(Sallah 2020)	USA	Qualitative: informal consultations & reflection				X	
(Schifeling and Hoffman 2017)	USA	Qualitative: documentary analysis			X		
(Schweizer et al. 2009)	USA	Qualitative: participatory methods, informal consultations & reflection				X	
(Selin, 2016)	Multi-country (primarily USA, some European)	Qualitative: informal consultations & reflection, quantitative analysis of survey data, interviews	X				
(Senbel, Ngo, and Blair 2014)	Canada	Mixed methods: pre- and post-questionnaire, interviews					X
(Sloane and Wiles, 2020)	USA	Mixed methods: pre- and post-questionnaire, quantitative and qualitative analysis of survey data	X				
(Smith, Banet, and Martinez Romera 2019)	Multi-country (Europe & US)	Qualitative: informal consultations & reflection, qualitative analysis of survey data	X				



(Stephens, Frumhoff, and Yona 2018)	Multi-country (USA & Canada)	Qualitative: documentary analysis			X		X
(Stojanovic et al. 2009)	UK	Qualitative: interviews		X		X	
(Stupar, Mihajlov, and Simic 2017)	Serbia	Quantitative: Pre- and post-questionnaire, statistical analysis	X				
(Summerton et al. 2019)	UK	Mixed methods: quantitative and qualitative analysis of survey data	X			X	
(Suartha and Sari 2013)	Multi-country (primarily USA and Indonesia)	Mixed methods: participant-observations, quantitative analysis of survey data					X
(Swearingen White 2009)	USA	Qualitative: documentary analysis					X
(Taylor et al. 2016)	South Africa	Mixed methods: quantitative analysis of survey data, informal consultations & reflection, interviews				X	
(Theobald, et al., 2015)	USA	Quantitative: pre- and post-questionnaire	X				
(Thomas, Jennings, and Lloyd 2008)	Multi-country (Australia and NZ)	Mixed methods: quantitative and qualitative analysis of survey data	X				
(Thorn et al. 2017)	USA	Quantitative: quantitative analysis of survey data				X	
(Tiemann, Fichter, and Geier 2018)	Multi-country (USA and Germany)	Qualitative: documentary analysis, interviews	X				X
(Tobin et al. 2017)	USA	Quantitative: quantitative analysis of survey data				X	
(Tomas, et al., 2019)	Australia	Mixed methods: informal consultations & reflection, quantitative and qualitative analysis of survey data	X				
(Tremblay et al. 2008)	Canada	Mixed methods: interviews, assessment of ice coverage, GIS/GPS mapping/modelling				X	
(Uddin, Okai, and Saba 2017)	Malaysia	Qualitative: informal consultations & reflection					X
(Vaziri and Kellier 2009)	USA	Qualitative: informal consultations & reflection					X
(Waliczek, McFarland, and Holmes 2016)	USA	Quantitative: quantitative analysis of survey data					X
(Wasco 2019)	USA	Qualitative: informal consultations & reflection	X				
(Wesselink and Gouldson 2014)	UK	Qualitative: interviews				X	
(Whitehouse et al. 2017)	Australia	Qualitative: qualitative analysis of survey data				X	
(Yoho and Rittman, 2018)	USA	Qualitative: documentary analysis	X				



Climate-U

Transforming Universities
for a Changing Climate

About Transforming Universities for a Changing Climate

Climate change is the most significant global challenge of our time, and many of its effects are felt most strongly in the poorest communities of the world. Higher education has a crucial role to play in responding to the climate crisis, not only in conducting research, but also through teaching, community engagement and public awareness. This study contributes to our understanding of how universities can enhance their capacity for responding to the climate crisis through research with universities in Brazil, Fiji, Kenya, India, Indonesia, Tanzania and the UK. In doing so, it contributes to the broader task of understanding the role of education in achieving the full set of Sustainable Development Goals.

Our partners

