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Education for Sustainable Development: a review of the literature 2015-2022

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Acknowledgements

This work was funded with a £5000 grant from Advance HE. We are grateful to King's Academy, particularly Sam Smidt and Ayesha Ahmed, for enabling the corresponding author to carry out this work and for topping up funding for the research assistants. The project benefited from the systematic reviewing expertise of Sonya Di Giorgio and Karen Poole in King's College Library, who peer reviewed and honed the search strategy. The guidance, support and feedback offered by the Advance HE Advisory Group members Kay Hack, Stuart Norton, Daniella Tilbury and Kim Ansell were vital to sustaining us and keeping us focused.

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Executive summary

Introduction and purpose

This review is a response to interlinked, global problems that need urgent attention. Humanity needs to reduce greenhouse gas emissions by transforming how we use land, generate energy and consume resources. There is no other way to reverse the widespread and rapid changes in the ocean and atmosphere, which are already causing biodiversity loss, food insecurity, wildfires, flooding, damage to infrastructure, infectious diseases and population displacement. We need to change how we produce, use and dispose of plastics to avoid devastating effects on biodiversity and health. If we succeed in eliminating air pollution, we will be addressing a major global environmental health risk and saving millions of human lives annually. If we take up alternatives to intensive farming and agrochemical misuse we can conserve soil, which has a vital role in nutrition, biodiversity and climate change mitigation. These and further problems are attributed to human consumption and pollution, and their solutions depend on human action (Food and Agriculture Organization of the United Nations, 2023; Grabiel et al, 2022; Intergovernmental Panel on Climate Change, 2023; World Health Organisation, 2021).

Although such existential threats require urgent attention, sustainable development is more encompassing than environmentalism alone. Sustainable development means limiting human activities to create a safe space for operating within planetary boundaries (Dlouhá et al, 2019) in a way that prioritises the needs of all life forms (Bianchi et al, 2022). It recognises that historical and ongoing contributions to the damage are not evenly distributed among humanity, and seeks a balancing of social equity, economic prosperity and environmental protection. These are often referred to as the "triple bottom line" (Elkington, 2018) or "three pillars", and are set out in the Sustainable Development Goals (Ilham et al, 2020). Their inter-relationship means that sustainability problems are stubborn, 'wicked' problems. These are "characterised by their resistance to definition, having no right or wrong answers, and their unfamiliar, ambiguous, chaotic nature, in which conflicts of interests among multiple stakeholders are inevitable" (Gulikers and Oonk, 2019). However, awareness of these problems has not so far brought solutions. In fact, over-focus on sustainability problems has left a wide gap between sustainability concern and sustainability action. Education for Sustainable Development (ESD) attends to that gap. If we in higher education are committed to preparing our students for the future, we need to teach them how to reverse current damage and contribute to sustainability, and to learn how to do this ourselves.

Education for Sustainable Development is defined by UNESCO (2023):

> "ESD gives learners of all ages the knowledge, skills, values and agency to address interconnected global challenges including climate change, loss of biodiversity, unsustainable use of resources, and inequality. It empowers learners of all ages to make informed decisions and take individual and collective action to change society and care for the planet. ESD is a lifelong learning process and an integral part of quality education. It enhances the cognitive, socio-emotional and behavioural dimensions of learning and encompasses learning content and outcomes, pedagogy and the learning environment itself."

ESD is often discussed in terms of developing competencies to meet the Sustainable Development Goals agreed by the United Nations. Competency is defined as "a complex combination of knowledge, skills, understanding, values, attitudes and desire which lead to effective, embodied human action in the world, in a particular domain" (Oanh, 2018). In the Education for Sustainable Development Guidance published for the higher education sector, Advance HE and the Quality Assurance Agency (2021) adopted the eight UNESCO competencies for sustainability. These are:

+ Ways of Thinking: systems thinking, future thinking and critical thinking
+ Ways of Practising: strategic, collaborative and integrated problem solving
+ Ways of Being: self-aware and normative.

Although these competencies are already widespread as intended learning outcomes in university degree programmes, they are not inherently oriented to sustainability. This means that the extent to which they advance sustainability depends on other educational elements. These are: sustainability problems to address; sustainability knowledge and values to bring to those problems; integration with disciplinary learning; encounters with other disciplines and their contrasting perspectives; and a prioritisation of sustainability across all the functions of the whole institution. There is broad agreement that ESD depends on participatory and experiential learning methods which engage students, deepen their understanding and mobilise them to act (Mburayi and Wall, 2018; Mokski et al, 2022; Sterling, 2012; Tijsma et al, 2023; Weiss et al, 2021; Weiss and Barth, 2019).

ESD recognises that education in its current form is unsustainable and requires radical change. The goal here is large-scale collective transformation of a profound nature, beyond changing personal values and consumer behaviour. Universities are uniquely placed to bring this about, as collectivities of learners and researchers in a range of disciplines with a civic concern that connects them with their local communities and the world of work.

This review inquires into the most advantageous approaches for ESD. At the beginning of the timeframe for the review – which also marked the end of the UN Decade of Education for Sustainable Development – a report from the Higher Education Academy noted the trial-and-error nature of much ESD (McCoshan and Martin, 2014). It is clear from more recent ESD reviews that, since then, research has not advanced as quickly nor as far as hoped. The empirical literature has been characterised as descriptive and case based, with a gap between concept and practice (Acosta Castellanos and Queiruga-Dios, 2021; Evans and Ferreira, 2020; Probst, 2022; Shephard, Rieckmann and Barth, 2019). There are calls for research to progress beyond aims and objectives to actually integrating ESD in university curricula (Lozano et al, 2017). In response, this review sought to understand:

1. How has ESD been framed within curricula and how have ESD principles been operationalised as learning outcomes?
2. What ESD pedagogies, assessments and teaching approaches are used, and why?
3. What student outcomes and perceptions are associated with these ESD practices, and what barriers are encountered?

Methods

To answer these three questions, a systematic review of research since 2015 was undertaken with a focus on explanatory studies linking pedagogical approaches to student outcomes. The body of literature about ESD is large and varied and ESD terminology has not settled, so academics and specialist systematic review experts worked together to focus the search. The search methodology is presented in detail in 'Appendix - methods'. We screened 3,253 publications and included 166 for review. In the database accompanying this report you will find the reviewed publications digested and presented for comparison.

Insights

The review found a research literature that is abundant but limited in scope, mostly in the form of case studies of single courses. ESD is not yet a mature approach, and the publications reviewed do not provide coherent insights into what should be learned and how. Pedagogical assumptions held by sustainability education scholars tend to be under-researched and under-evaluated (Acosta Castellanos and Queiruga-Dios, 2021; Evans and Ferreira, 2019; Probst, 2021; Redman, Wiek and Barth, 2021). There is a tendency in some recent reviews to decontextualise teaching approaches from their curriculum contexts and disciplinary learning outcomes, raising questions about the generalisability of their findings (Lozano et al, 2019; Park, Licon and Sleipness, 2022). Students' prior learning, predispositions and expectations are rarely investigated (Rodríguez Aboytes and Barth, 2021). The gap observed in wider society between sustainability concern and sustainability action continues to be reflected in university student outcomes (Pujol and Tomás, 2020; Weinberg et al, 2020).

However, research is becoming more focused and is beginning to shed light on the kinds of settings and approaches associated with transformative outcomes. For practitioners open to working with promising ideas, this literature yields insights for educators, leaders and researchers.

+ **The 'wicked' nature of sustainability problems requires interdisciplinary and transdisciplinary work across boundaries between disciplines, and between universities and wider society.** These terms do not have settled definitions, so in this review, **interdisciplinarity** is defined as the integration of different academic fields, and transdisciplinarity as bringing academia and wider society into contact to draw on each other's insights for mutual progress (Horn et al, 2022; Klein, 2017; Scholz, 2020; Tijsma et al, 2023).
+ **To be transformative, sustainability education must integrate knowledge, competencies, values and readiness to act.** Scientific knowledge brings students awareness of sustainability problems. Competencies empower students to take action. Values are the difference between awareness and concern. Readiness to act is the difference between concern and intent. Some of these may be more readily formalised as intended learning outcomes, some are impossible to assess, but all are needed.

+ **ESD aims for radical transformation; it depends on confronting and transgressing existing paradigms and practices.** This is likely to be received as troublesome, and it is important to engage with this emotional dimension.
+ **A single one-shot sustainability course is unlikely to bring the transformed mindset and competencies needed to contribute to systemic change.** Students are likely to face inertia or resistance in their communities and workplaces, meshing them in existing socio-economic structures, steering them towards incremental change and technocentric efficiency approaches and deterring them from contributing to the kinds of radical change that are needed. Sustainability requires time and opportunities to integrate knowledge, competencies, values and readiness to act.
+ **Integrating ESD into core disciplinary curricula is most associated with transformative, lasting learning,** although this approach is demanding to design, teach and assess. Ultimately it depends on institutional leadership to resource continuing professional development (CPD) for educators redesigning curricula, as well as time for teaching and coordination activities such as monitoring, administration and liaison.
+ **The teaching approaches most associated with developing sustainability competencies** are project- or problem-based learning across disciplines, projects with external partners, real-world examples and conceptual approaches such as environmental justice. There is no standardised formula for these pedagogical decisions. Educators, with their integrative knowledge of subject, pedagogies, students and contexts, are pivotal to deciding on the optimal approaches for their context.
+ **The teaching approaches most associated with developing transformative sustainability values** stimulate critical reflection and self-reflection. Critical reflection brings external perspectives to analyse the world and one's own underlying assumptions. This takes time, can be disorientating, and requires guidance, support and social interaction between and among students, educators and wider society, bringing diverse perspectives.
+ **Interdisciplinary project work within traditional university structures is demanding and requires support for academics and students.** The promise of interdisciplinary groups resides in the different perspectives members bring. Inevitably, these differences also complicate reaching consensus on the nature and underlying causes of the problem to be addressed. This integration of knowledge is a bottleneck. A second bottleneck is agreeing on concrete, specific, well-defined plans which are feasible to execute, yet fully engage with the complexity of sustainability problems. Unsupported, these negotiations often bring delay, misdirected effort, frustration and aversion to this kind of learning. Students are likely to need support to communicate their disciplinary understanding to non-specialists. Academics who are less experienced in interdisciplinarity need support for holistic, integrative teaching.

+ **In transdisciplinary collaborations with external partners, students need to be challenged and guided to make the most of the opportunities presented.** The diversity in external partnerships means it cannot be assumed that partners or students understand the collaboration as potentially transformative. Students need to be able to represent their own expertise and search out ways to learn from the partners. They need to clarify their vision, how it incorporates multiple perspectives, and the partner's involvement in it. This may not be intuitive but it can be scaffolded.
+ **Competencies associated with sustainable development already exist in many degree programmes, though unevenly addressed and often in the absence of explicit sustainability content.** Competencies tend to be more explicitly addressed in applied disciplines such as engineering, business and education where graduates are expected to have tangible influence on sustainability, but less so in pure disciplines such as maths and literature, and pressured curricula such as health professions. These require careful consideration to align sustainability with intended disciplinary outcomes.
+ **Where ESD is transdisciplinary, local, familiar settings may feel closer to students' reality and more meaningful than remote ones.** These may be partnerships, site visits, or fieldwork. Local context allows students to develop a more observant, involved relationship with their environment. This offers great potential for transforming beliefs and behaviours.
+ **There are signs that maturity and level of study are associated with students' successful navigation of the frustration and complexities** of real-world sustainability work in interdisciplinarity and transdisciplinary settings. However, this may only be true where students have not had earlier experience in these areas or have not been adequately supported to engage in them previously. This may have implications for the timing of project work with external partners and interdisciplinary groups, and preparation for this kind of work earlier in a degree programme.
+ **Formally assessing ESD is often difficult.** When assessing competencies, there is a need for practices and instruments which reduce reliance on the prevalent self-reported approaches to assessment. There is debate whether some sustainability values should be assessed at all.
+ **ESD needs more conceptual precision.** There is concern that interpretations of ESD terminology have become so broad that the words can no longer effectively communicate meaning. Blunt concepts interfere with productive engagement and are thought to be contributing to overall slow progress with ESD. ESD work should take time to reach shared understandings.
+ **Evaluation of ESD is limited by scale and methods.** It often falls to busy educators to research and disseminate their own practice, bringing limitations which affect the quality of evidence. ESD literature reviews frequently flag over-reliance on students' self-reported learning and change, and educators' opinions and experiences. These are valid sources of evidence but need to be triangulated with others. The case-based nature of much research and frequent gaps in reporting makes it difficult to transfer the findings with confidence. With rare exceptions, evaluation of ESD currently lacks longitudinal follow-up for evidence of hoped-for transformative outcomes and whether these can be connected to specific aspects of a curriculum.

Recommendations and implications

Below we summarise recommendations and implications for leaders and for educators.

For educators

+ **Integrate sustainability into core curricula wherever possible.** This approach is most associated with the transformative goals of ESD because it treats sustainability as part of the discipline rather than adjunct.
+ **Aim to integrate the interdisciplinarity in ways that reinforce students' disciplinary learning.** Designing interdisciplinary group work to build on disciplinary learning helps to reach all students rather than only the willing. It helps to persuade students of the relevance of sustainability where this is not obvious. Most straightforwardly, this could take the form of giving students sustainability problems or cases through which they practice applying new disciplinary skills or concepts. At its most advanced it could take the form of incorporating inter- or transdisciplinary sustainability learning into a disciplinary degree programme.
+ **Prepare to communicate the concepts of sustainability and their inter-relationships to students and colleagues.** This will help to address longstanding problems conceptualising sustainability. Reaching a shared understanding of these in each context will help with consistent, productive engagement. Rubrics describing assessment criteria and levels of achievement are promising starting points for discussion here.
+ **Create space for students to interpret learning outcomes and assessment criteria together.** This is already widely accepted as beneficial, but is particularly important in interdisciplinary or transdisciplinary settings since these often bring contrasting approaches to a single task. This clarification needs to be a collective process to contextualise the learning outcomes and criteria and interpret what is ambiguous.
+ **Consider how to maintain focus on learning outcomes that are aspirational but will not be assessed for academic credit.** These may include competencies and values such as self-awareness and willingness to act for sustainability. Where there is a decision not to assess these, they are unlikely to be formalised as learning outcomes and are prone to be obscured. Bringing them to the fore is particularly important where ESD is embedded into disciplinary learning.
+ **Guide students to integrate knowledge in interdisciplinary settings.** Students generally need support to integrate different disciplinary knowledge, beyond simply accumulating it. A common topic or theme brings valuable focus here. Where courses are team-taught by disciplinary specialists across faculties, coming together for early introductory framing and concluding synthesis sessions can model for students how different disciplines can respond to each other as they address a given problem.

+ **Facilitate students' interdisciplinary and transdisciplinary group and project work.** Students need methods, facilitation and time to navigate common difficulties of problem identification and action planning, and to become effective group members. Specific guidance and methods enable students to comprehend and engage with other perspectives, represent their ideas, reach consensus, and manage the work equitably. Examples include concept maps to visualise perspectives and focus points of difference, causal trees to arrive at a shared problem definition, joint data analysis, and structured approaches to dialogue and communication.
+ **Incorporate teaching approaches and learning activities associated with sustainability competencies.** Teaching approaches that are already widely established in disciplinary curricula are promising in developing the widest range of sustainability competencies. These are project-based or problem-based learning, real-world experiences or cases. Other teaching approaches associated with environmental education and community and social justice are useful in teaching narrower groups of competencies. No single approach addresses all sustainability competencies, but they can be combined in purposeful ways.
+ **Create space and structure in the curriculum for critical reflection.** This is key to developing values which mobilise sustainability knowledge and competency into action. Reflection – a process of analysing content, process and premises in the light of alternative perspectives – is key to the development of values and subsequent intention to act. Students need guidance to move from descriptive to critical levels of reflection through which they come to question underlying premises in the world and in themselves.
+ **Anticipate demographic and disciplinary differences about what is perceived as appropriate when tackling sustainability problems and dilemmas.** Consider how these should shape the curriculum, teaching and assessment so that every student develops sustainable values, competencies and intention to act, and no student is at a disadvantage. Take steps to ensure that no single perspective dominates ESD and that every student can find a personal connection with it.
+ **Engage with CPD.** Not all educators will become interdisciplinary ESD specialists. Those who do take this role will need to research the relationship between their own discipline, other disciplines and sustainability, and how to teach this to students. Of particular relevance to ESD is CPD around interdisciplinary team teaching, teaching sustainability competencies and values, stimulating and guiding critical reflection, identifying focusing questions and problems for students, teaching students methods for working in interdisciplinary groups and with external partners, facilitating project- and problem-based learning, managing emotion and maintaining hope, and developing a repertoire of teaching approaches associated with sustainability learning outcomes.

For leaders

+ **Define ESD** in ways which bring clarity to the terms used in outcomes such as skills, competencies or capabilities. Aim for an institution-wide shared understanding of these basic ESD concepts.
+ **Strategise to integrate ESD in core degree curricula.** To bring change, ESD needs to be approached as a recurring process through which students deepen their knowledge, values and competencies in systematic and holistic ways for the duration of their degree programme. This needs to be done in ways which do not compete for academic attention with disciplinary learning nor with other sector agendas such as careers, cultural competency, inclusivity, entrepreneurship and digital capabilities. An integrated approach to curriculum design is needed.
+ **Establish ESD as an institutional concern.** Much ESD currently depends on charismatic, motivated individuals and is vulnerable if those individuals move on. A 'whole university' approach encompassing all parts of the institution will help with integration and avoid hidden curricula where students pick up messages from the institution which conflict with what they are being formally taught about sustainability.
+ **Offer an institution-wide interdisciplinary sustainability course that reinforces students' degree specialisms**. For students whose core curriculum does not include ESD, an extra-curricular course may be their only opportunity to learn about sustainability at university. Extra-curricular courses are not associated with transformation in the publications we reviewed, but there are signs that they could be transformative if they are interdisciplinary, transdisciplinary and designed to reinforce each student's degree specialism. This also makes it possible for the course to be recognised as complementary and eventually adopted into degree programmes. To be credit-bearing, such a course will need an administrative home. To be transformative, its educators and leaders will need to be resourced to undertake the considerable work involved in inter- and transdisciplinary learning.
+ **Resource continuing professional development for sustainability educators and enable them to prioritise it.** CPD is considered a key driver for ESD. Educators facing competing priorities need permission and reason to treat the CPD as important and urgent, so that it is not the first thing to be sacrificed under pressure. Of particular relevance to ESD is CPD around interdisciplinary team teaching, teaching sustainability competencies and values, stimulating and guiding critical reflection, identifying focusing questions and problems for students, teaching students methods and techniques for working in interdisciplinary groups and with external partners, facilitating students project- and problem-based learning, managing emotion and maintaining hope, and developing a repertoire of teaching approaches associated with intended learning outcomes.

+ **Resource long-term research, development and evaluation to improve progress with ESD.** This will help to bring conceptual clarity to learning outcomes and galvanise the development of assessment instruments and practices. Of particular importance are long-term follow-up studies which draw connections between ESD teaching approaches, students' influence on sustainability in their communities and workplaces, and the consequences of this influence. This will shed light on demographic differences in how students respond to ESD, and feed back into curricula and teaching approaches.
+ **Reward interdisciplinarity.** Interdisciplinarity is essential to ESD. It needs to be appropriately resourced and valued in recruitment and promotion criteria. At the same time, it is important to maintain disciplinarity specialisms so that fruitful interactions can occur between them.
+ **Support educators through the challenges of disciplinary curriculum design.** Standardisation will not work here because, without educators' agency and personal engagement, the quality of education will degrade. Moreover, various professional bodies who accredit degrees will differently influence how ESD is addressed. At the same time, building consensus across disciplines can be time-consuming and not every educator can be expected to develop pedagogical familiarity with disciplines beyond their own. Consequently, to develop interdisciplinary and transdisciplinary curricula, universities need efficient, energy-conserving approaches to requirements gathering and consensus generation which involve all stakeholders while avoiding intensive, bottleneck-prone processes. Division of labour between disciplinary and interdisciplinary educational scholarship and teaching is possible.
+ **Enable work with external partners through capacity building and resource.** To realise the mutual transdisciplinary benefits of external partnerships, this review has underlined the need for expectation management, preparation, structure and close liaison for both the students and the partners. In some degree programmes – particularly those which are professionally oriented – work with external partners is already well-established and supported by dedicated placement team. In other disciplines, links and established ways of working with external partners do not yet exist and need to be resourced.
+ **Build capacity for central and faculty leadership, and support for change.** This entails deciding which aspects of ESD should be standard across an institution, which need a local or thematic focus, and which should be devolved for individual educators and students to interpret for their own context. This support should be formalised in strategy and policy.
+ **Incentivise programme and module leaders to make the transition.** ESD curricula are often open and differentiated, requiring constant calibration and intervention. This makes them demanding to design, set up and maintain. At the beginning ESD curricula typically require extra investment of time and energy. Unfamiliar pedagogies and ways of working may cost more initially until they bed down. The most transformative ESD courses are particularly effortful for the leaders of those programmes and courses, requiring coordination, monitoring, liaison and frequent intervention, particularly where there are external partners. There is a need to address the high workloads currently impeding educators' engagement with these potent approaches to ESD.

+ **Enable large scale, valid and longitudinal approaches to evaluation.** Follow-up evaluation will reveal the extent to which the effects of ESD diminish over time. Practical support from researchers or evidence-bringers specialised in educational research methods can relieve some of the pressure on individual educators to research and disseminate their own practice, and is likely to improve the quality and transferability of the evidence.
+ **Incentivise dissemination.** Disseminating ESD practice is vital to its progress, yet – outside Educational Studies departments - publishing on education is often peripheral to academic reward and recognition structures. Moreover, the demands of designing, teaching and sustaining ESD are likely to divert time and energy from researching and publishing about it. Support and recognition for contributing to the sum of what is known about ESD is therefore needed.
+ **Engage with resistance.** Addressing an increasingly mechanistic paradigm of education requires staff and students to value unsettling modes of teaching that are not always welcomed. It will also entail de-escalating competition and enabling cooperation within and between institutions. ESD is likely to advance further and more quickly where it works with the grain of existing strong disciplinary identities and missions. University leaders will play a major role in persuading their academic communities to commit to ESD and prioritise it.

For researchers

+ **Aim for conceptual clarity in ESD terminology.** Reviewers of ESD literature have found it difficult to know what is being researched since empirical publications frequently omit to define the intended learning outcomes of their interventions or how these can be recognised. To progress with ESD research, clarity is needed.
+ **Carry out large-scale, multi-institutional, well-contextualised explanatory research.** There is an abundance of case studies, but these do not readily lend themselves to generalisation. There is a need for well-contextualised research drawing causal connections between teaching approaches and sustainability outcomes.
+ **Carry out long-term follow-up studies.** ESD is dedicated to future action, yet there is a lack of follow-up research. It is important to know more about what students do with the sustainability knowledge, competencies, values and intentions to act. Under what circumstances do graduates achieve change in their workplaces and communities? What is the role of their education, and what factors are to do with the communities, workplaces and other external factors? What are the consequences of the action? These questions are hard to answer but necessary to pursue.
+ **Reduce reliance on self-reported learning or change as an evaluation approach.** It is one of the most available approaches to an under-resourced researcher, but it is compromised by social desirability bias and students' misjudgements. The publications reviewed offer very fleeting glimpses of theories which may be of use to discerning transition and epistemological development.

+ **Distinguish between academic assessment and educational evaluation.** If assessment is valid, it can contribute to evaluation. However, a primary purpose of academic assessment is to determine students' performance in relation to a desired standard. As such, assessment tends to be short term and oriented to learning outcomes. On its own it is unlikely to reveal causal relationships between curriculum design, teaching approaches and longer term sustainability outcomes. It is unlikely to say much about students' internal processes of integrating, knowledge, competencies, values and becoming ready and willing to act.
+ **Generate instruments and practices to assess sustainability learning.** Instruments such as rubrics can help students understand the nature of tasks which may otherwise be obscure, how to succeed and how to assess their own performance.

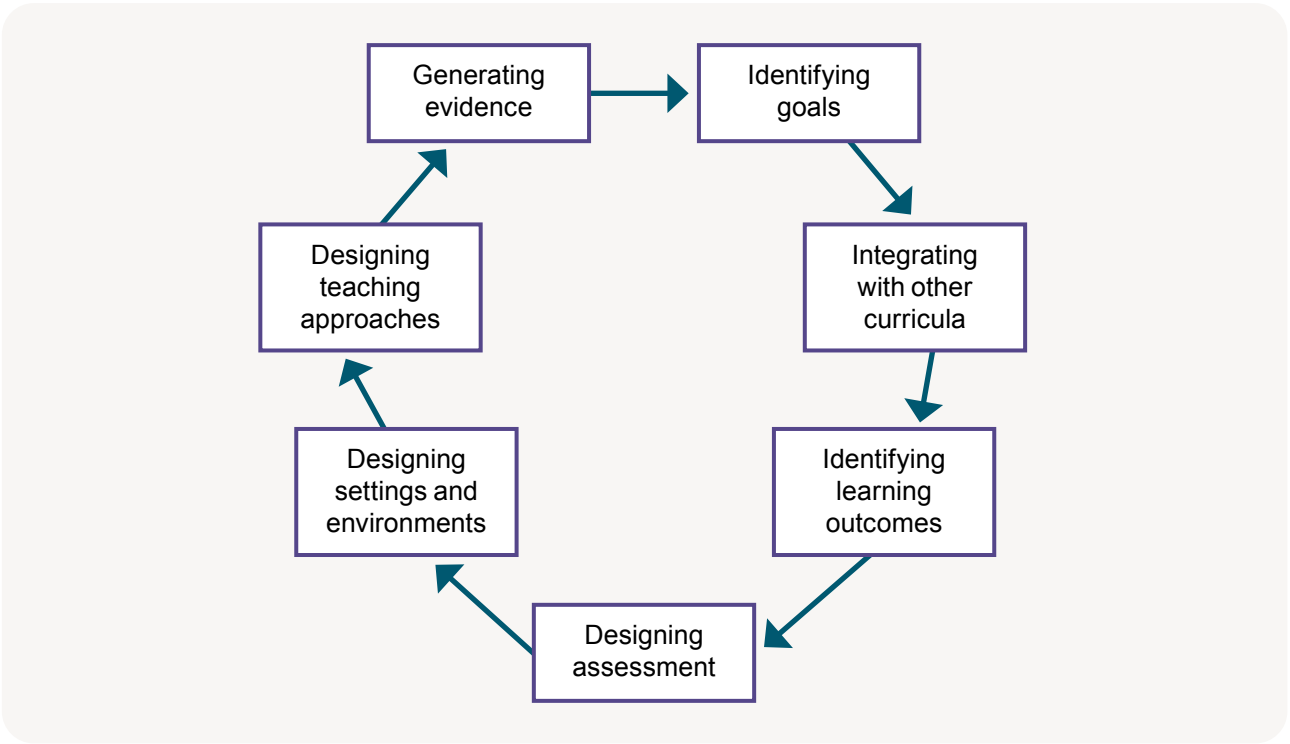
Limitations

Of necessity, the literature search had to balance specificity and scope to return empirical publications on higher education for sustainable development. By using the sustainability competencies to focus the ESD concept (see 'Appendix - methods' for the rationale), we unavoidably ruled out some relevant work. Though the review touches on sustainable entrepreneurship education, campus-as-living-lab and whole-institutional approaches to supported ESD, fewer publications in these areas were included than anticipated; dedicated searches are likely to bring insights here. In most articles we discovered references to publications our search strategy had not captured, or which we screened out at the filtering stage. These look useful for particular contexts and can be discovered through subject keyword searches and citation tracking. They tend to be case based, richly specific, and may relate to purposes, practices and outcomes in their contexts more closely than some of the higher-level evidence in this review. There are questions we did not have the capacity to pursue, such as the number of hours dedicated to ESD in different settings, or the prevalence of different curriculum benchmarking or design frameworks. Academic fields and global regions are not evenly represented in our search results, and we did not have capacity to pursue the underrepresented ones through dedicated searches. Like many of our predecessor ESD reviewers, we lacked the capacity for translation and screened out publications in languages other than English. We recommend that national higher education bodies work with international counterparts to address this deficit, which almost certainly overlooks countries in the global south and outside the OECD. Another source of uneven geographical representation can be traced to our brief, which focused on links between curricula and learning and therefore excluded work in international settings that were in the earlier stages of ESD, such as advocating for resources or seeking insights about baseline perceptions of sustainability. Finally, we assume that much good work in ESD is unpublished due to lack of resource for research and dissemination. Identifying this requires a different approach from a systematic literature review.

Structure of this report

Sustainability is complex, and it follows that ESD is also complex. In the body of work reviewed we encountered uneven representation of academic disciplines, prevalence of single cases and limitations in methods and reporting. It is not straightforward to generalise from this very diverse work. However, we anticipate that readers will come with questions related to their own contexts. This has led us to adopt a narrative approach to the report. To organise the findings, we selected a framework (Figure 1) which presents ESD in terms of systematic curriculum design (Dee Fink, 2003; Wiggins and McTighe, 2005). This has enabled us to respond to the three questions above and to approach ESD holistically. We hope to avoid over-focus on the role of teaching approaches and learning activities, since while these are influential, they are themselves constrained and shaped by purposes, intended learning outcomes, settings and assessment approaches. This lens of curriculum design allows us to consider how these elements and processes can align to deepen learning.

Figure 1. This report is structured according to a curriculum design framework (after Dee Fink, 2003; Wiggins and McTighe, 2005)



Our first findings section, ‘Identifying goals and aims of ESD’, summarises how the goals have been conceived in this literature. The next section, ‘Integrating with other curricula’, focuses on how ESD has been positioned in relation to students’ degree curricula, whether integrated, adjunct or something in between. The following section, ‘Identifying learning outcomes’, discusses the inter-relationship of knowledge, competencies, values and readiness to act, and how these have been made explicit to anchor the curriculum to its purposes. Next comes a section on ‘Designing assessment’, which introduces a range of methods through which students can demonstrate they have achieved those learning outcomes, and which orientate the teaching approaches. Then we turn to ‘Designing settings and environments’, including interdisciplinarity and transdisciplinarity, which support learning about sustainability but are challenging to implement. A section on ‘Designing teaching approaches’ then explores how knowledge, competencies, values and readiness to act are being taught. Finally, the section on ‘Generating evidence’ focuses on creating feedback into the design process.

There is plenty to query about our decision to organise the report in this way. As we will discuss, much of what is distinctive and transformative about ESD is emergent and evades fixed learning outcomes and assessment approaches. However, this body of literature was so large and varied that we needed a way to make sense of it and present it to readers. Since educators are pivotal to ESD, we decided on a framework which is most likely to be familiar to them, as well as to the university leaders and policymakers who enable them, and to researchers concerned with their practice.

What is ESD?

Education for Sustainable Development (ESD) is defined by UNESCO (2023):

> "ESD gives learners of all ages the knowledge, skills, values and agency to address interconnected global challenges including climate change, loss of biodiversity, unsustainable use of resources, and inequality. It empowers learners of all ages to make informed decisions and take individual and collective action to change society and care for the planet. ESD is a lifelong learning process and an integral part of quality education. It enhances the cognitive, socio-emotional and behavioural dimensions of learning and encompasses learning content and outcomes, pedagogy and the learning environment itself."

Examining this definition illuminates key aspects of ESD. **Sustainable development** refers to "meet[ing] the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). Global consultation on what this entails has generated the Sustainable Development Goals (SDGs), a global framework adopted in 2015 by the United Nations to redirect humanity onto a more sustainable path (United Nations, 2023). These 17 SDGs address three connected dimensions of sustainability: environmental integrity, economic viability, and a just society. Because unsustainable systems are maladaptively resilient and resistant to change (Lotz-Sisitka et al, 2015), to reach the goals everyone needs to do their part. This demands a profound and swift transformation in how we think and behave. **Learners** need to be equipped to recognise unsustainable patterns, speak up about them, make informed decisions about how to amend them, and take responsible collective and individual action. **Education** is therefore considered a key enabler for achieving the other SDGs (UNESCO, 2017) and is explicitly recognised in SDG 4.

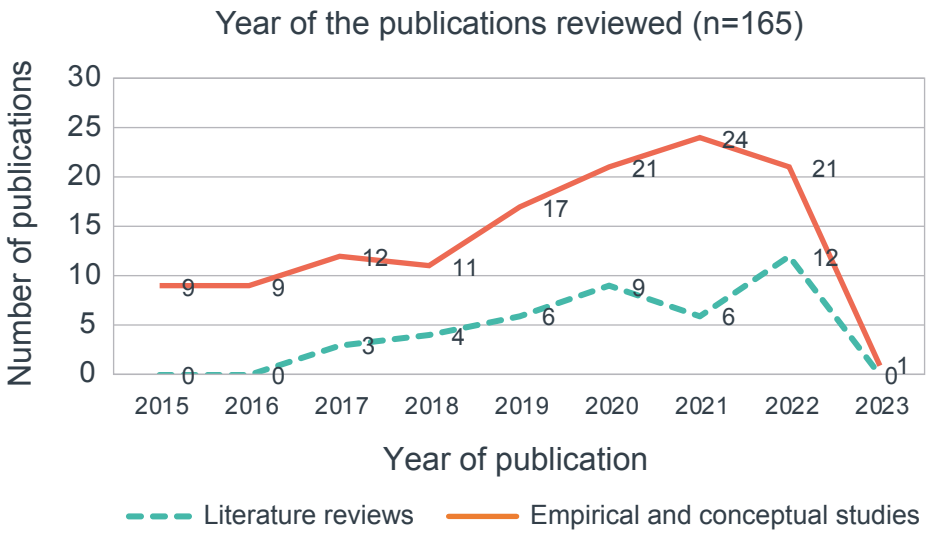
Working knowledge about the SDGs – the **cognitive dimension** in the definition above – is not, on its own, ESD. Sustainability problems are stubborn, 'wicked' problems, distributed across complex interconnected systems, dynamic, ambiguous, unfamiliar, lacking definitive answers. They have multiple stakeholders who draw on different sources of information, making them prone to conflicts of interest (Gulikers and Oonk, 2019). Addressing such problems requires the **socio-emotional and behavioural dimensions of learning** often referred to as sustainability competencies. These are the capacities, skills, values and volition which **empower** learners to act individually and collectively on their sustainability knowledge. A widely agreed set of competencies (UNESCO, 2017) is set out in Table 2 and can be found in the guidance published by Advance HE and Quality Assurance Agency guidance (2021).

There is broad agreement that ESD **pedagogies** are **participatory** and **active** learning approaches. At their most powerful they are based in real, locally meaningful sustainability cases, problems or projects. They emphasise the collective and collaborative, bringing together learners **diverse** in prior knowledge, assumptions and obligations to effect change. These pedagogies stimulate **critical reflection** through which learners interpret their learning experiences and relate them to the forces operating in the wider world (Bianchi et al, 2022; UNESCO, 2017; Tilbury, 2011). To bring about the needed **transformation**, ESD in higher education should be integrated with core curricula, enabling a holistic approach to developing learners' knowledge, competencies, values and motivation (the cognitive, behavioural and socio-emotional dimensions of the definition above). As core education within degree programmes, ESD should also integrate with students' disciplinary learning (Tijsma et al, 2023).

About the publications reviewed

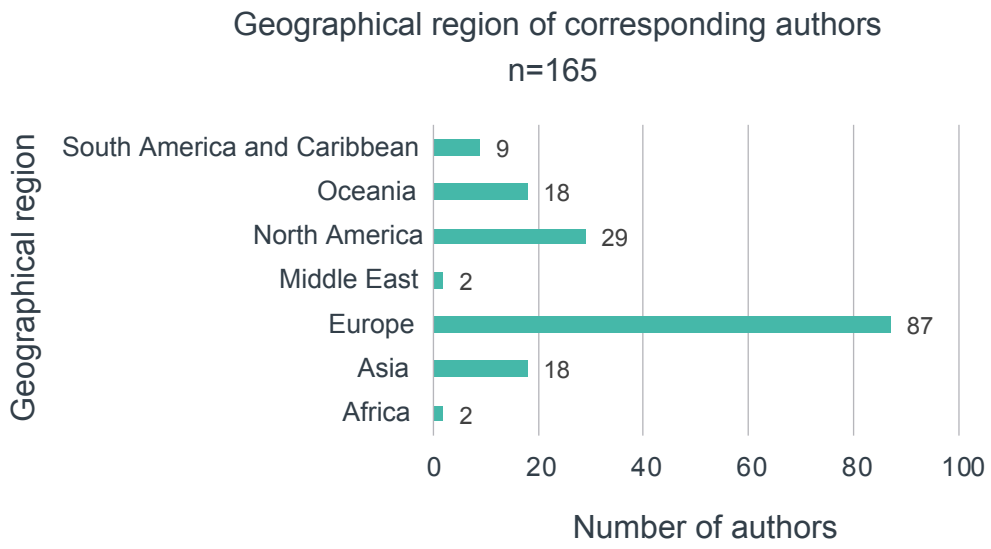
This review explores advances in ESD in higher education since the end of the UN Decade of Sustainable Development. Probst (2022), Evans and Ferreira (2020) and Acosta Castellanos and Queiruga-Dios (2021) also recently reviewed ESD literature to discover whether it is yet possible to identify pedagogies that lead to specific sustainability outcomes. Like them, we found that much research was descriptive and based in single cases, with learning processes and outcomes often thinly described and under-theorised. Much of the empirical research here has been published by its implementing lecturers as case studies of a course or unit, which is the kind of research associated with limited capacity. As Probst puts it, "[d]espite its volume, the literature did not provide coherent insights into what should be learned and how".

Figure 2. Year of publication of the studies reviewed. The search concluded on 4 November 2022.



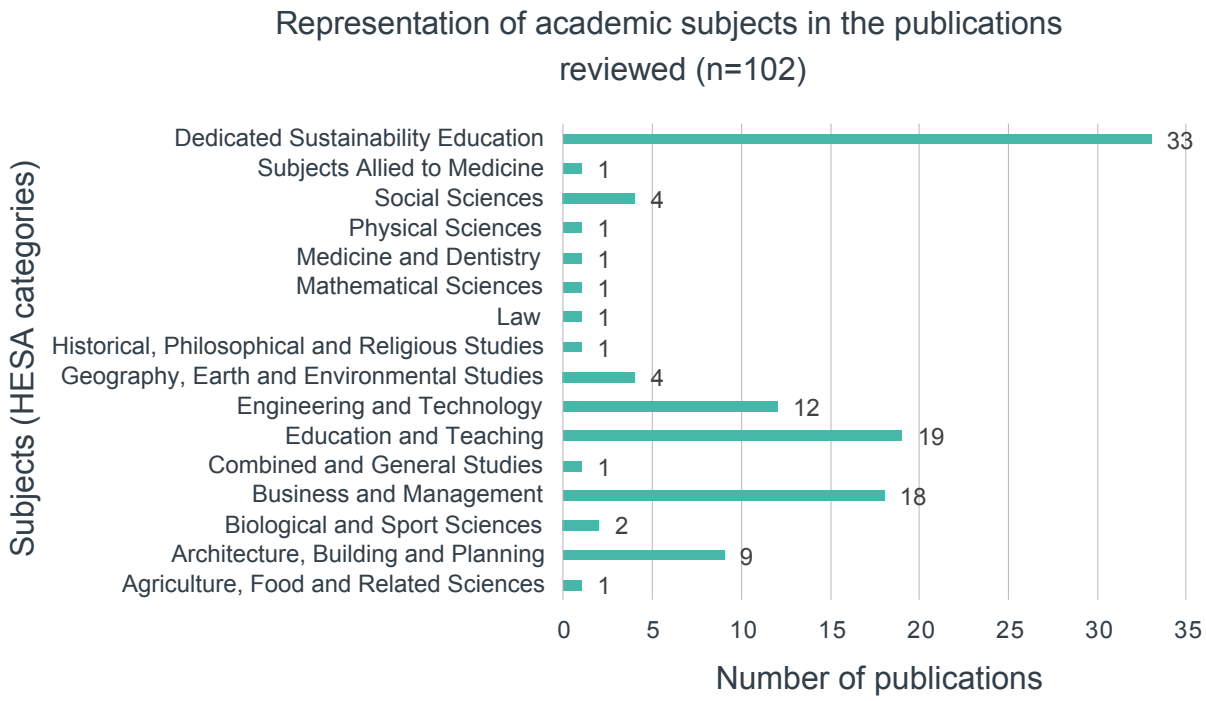
We observed the global disparities noted in earlier literature reviews. Overrepresentation of global northern and OECD countries may be a predictable consequence of English-only searches like ours. Even so, the more bibliometric and global literature reviews indicate that while some countries have begun to investigate the 'how' of ESD, others are still contending with the 'what' (Boarin and Martinez-Molina, 2022). Our criteria led us to exclude work at these earlier stages of resourcing ESD in Ethiopia and sub-Saharan Africa (Abadama, 2018), trying to understand baseline perceptions of ESD in Kosovo (Beka and Ciani, 2015) or exploring ESD in educational contexts other than universities in Jamaica (De Angelis, 2023). Beneath the headline numbers per country, Weiss and Barth (2019) found that countries with fewer publications may have a higher rate per institution than those with more, while high numbers in one country may be concentrated in only a few institutions.

Figure 3. Geographical region of corresponding authors of all 165 publications reviewed, based on the institutional address they provided. Note that the first author's region does not always reflect the site of the study nor the region of fellow authors.



Academic disciplines were unevenly represented, with more applied subjects than purer ones. It is interesting to note the low number of studies based in Geography, Earth and Environmental Studies. It may be that sustainability education has emerged from this subject area and into dedicated sustainability teaching which is more widely available across institutions and disciplines. Dedicated sustainability education is not included in HESA's subject grouping, but is the largest group we reviewed. Ultimately, where the sustainability education was designed for students from one or two subjects, we coded it according to those subjects, but where it brought together students from multiple subjects, we coded it as 'Dedicated Sustainability Education' (Figure 4). Interdisciplinarity is central to ESD, so the large proportion of dedicated sustainability education may indicate that institutions are currently finding it more straightforward to offer interdisciplinarity within a dedicated course than within the disciplinary learning in degree programmes. The most prevalent academic subjects in our dataset are Education and Teaching, Business and Management, Engineering and Technology and Architecture, Building and Planning.

Figure 4. Academic subjects in the publications reviewed, classified according to HESA's subject grouping. We have coded sustainability courses bringing together students from multiple subjects as 'Dedicated Sustainability Education'. The total omits publications that are not concerned with a course, unit, or particular subject.



Reflections

Our search strategy returned abundant and varied research literature allowing us a rich picture of ESD in some parts of the world, and we were alive to informal and nascent literature. Nevertheless, we are aware that other parts of the world (much of the global south, for example) are less represented. It was striking to discover from preceding ESD literature reviews how usual it is, even in this field of ESD with its global attention, to exclude languages other than English. This was true even where the first authors could be assumed to have first languages other than English. Clearly it is a non-trivial matter to conduct a multilingual search. We hope that funding organisations will address this gap, since it is implicated in this geographic unevenness.

Also less represented, we assume, is the work of academics teaching sustainability who have not had the capacity or encouragement to disseminate. We also assume that if it is hard to find time and energy to disseminate practice in wealthier countries, it is more so in less wealthy ones. To discover more about ESD in those settings would require research methods other than a systematic literature review.

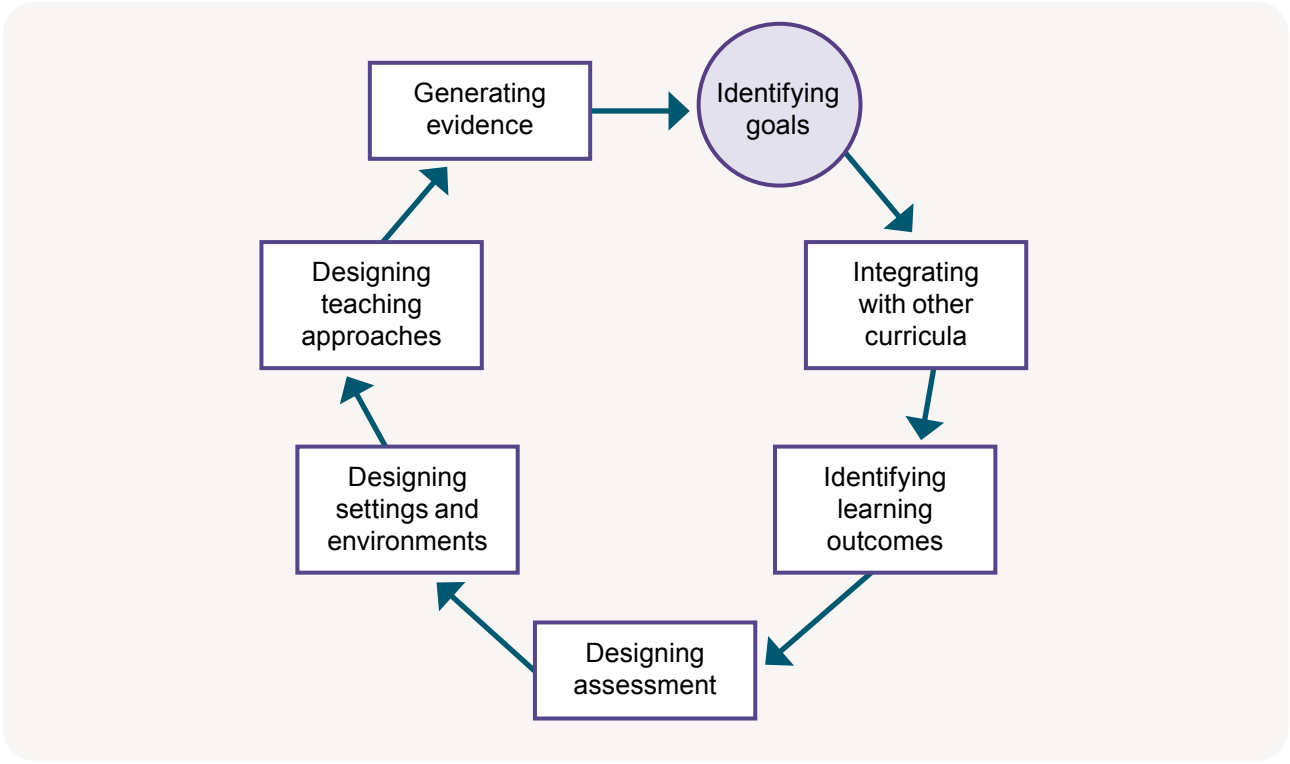
In most articles we discovered references to publications our search strategy had not captured. Sometimes they were using terms which alluded to ESD but were different from ours (Acosta Castellanos and Queiruga-Dios, 2021), or sometimes we had filtered them out according to our criteria. These look useful in specific contexts and can be discovered through subject-specific keyword searches and citation tracking. They are case-based and may relate purposes, practices and outcomes in more detail than some of the higher-level evidence in this review. Mindt and Rieckmann (2017) note that these authors have often studied and documented their own approaches well, and at a context-sensitive level of detail. This is helpful for building the confidence of academics and practitioners getting started with ESD. As Shulman puts it, “They weren’t looking for generalisations. They were trying to figure out what to do tomorrow. Because it mattered” (2013). As such, these case studies support practical judgement and case-based reasoning for ESD in particular academic subjects. At the same time, these works are not always clearly connected with the ESD learning frameworks introduced in this review, and do not always shed light on how these can be successfully operationalised. There is a need for clarity and focus here to make the most of scarce educational resource.

This review has taken longer than the four months indicated by Advance HE. It is not surprising that the volume and diversity of publications should reflect the complexity of sustainability itself; nevertheless it was imposing. The different academic disciplines, institutional and global contexts, epistemologies and reporting approaches made it hard to get into a rhythm and speed up. This variety also made it difficult to judge quality. Since we were alive to different disciplines and different curriculum approaches in different countries, we wanted to err on the side of inclusion. This was one reason we decided not to experiment with machine learning software at the filtering stage of this review. We feel our approach was solid and efficient. However, at the end of this process, having expended a disproportionate amount of energy on filtering, we are intrigued to know whether machine learning tools could have achieved the same or improved focus while saving time.

The dataset summarising the publications had a dual purpose: it helped us write the report and was destined to be published along with the report. As such, in each entry we came to realise that it is helpful to use the distinctive language of each publication as well as common terms across the database, so that both database and each publication can be more readily searched.

Findings

Identifying goals and aims of ESD



This first findings section grounds ESD in the overarching goals which express the difference it seeks to make in the world. Across the publications reviewed, ESD exists to enable society to tackle super-complex, wicked problems which demand multiple perspectives and do not have definitive correct answers (Advance HE and the Quality Assurance Agency, 2021; Gulikers and Oonk, 2019).
It provides an education in analysing these problems from different perspectives, working with others to bridge gaps between sustainability concern and sustainability action. This means that, as well as teaching knowledge and skills, ESD is also an education in values, aiming to transform students' worldviews, and build their capacity to alter wider society. In confronting established norms, these are inevitably transgressive goals.

Responding to supercomplexity is an overarching goal. ESD requires students to understand sustainability in terms of interrelations between economic, social and environmental concepts, which are often referred to as the three pillars (Mokski et al, 2022). Such problems are often referred to as 'wicked problems' (Davidson, Prahalad and Harwood, 2020), "characterised by their resistance to definition, having no right or wrong answers, and their unfamiliar, ambiguous, chaotic nature, in which conflicts of interests among multiple stakeholders are inevitable" (Gulikers and Oonk, 2019). The urgent nature of current global challenges demands that we learn for adaptability, uncertainty and, according to some predictions, chaos. Students need to understand complex systems both theoretically and as ethical agents. A successful response to supercomplexity depends on integrating alternative perspectives to address tensions between the environmental, social and environmental

elements of sustainability. It demands that we learn to live with ambiguity, frustration and being unsettled (Davidson, Prahalad and Harwood, 2020; Sanchez et al, 2019).

Social transformation is another overarching goal, which in liberal democracies requires a critical mass of personal transformation. Transformative ESD is intended to,

> "…nurture in students those qualities that enable them to thrive under deeply unsettled conditions and so make productive and meaningful contributions to solving wicked sustainability problems. First, such pedagogies facilitate personal characteristics of self-awareness, self-reliance and self-confidence to act purposefully in the face of uncertainty, and dispositions of openness and adaptability to cope with complexity. Second, cognitive, functional and affective competences are developed through practical, reflective, problem-based learning experiences in interactive, collaborative and paradigm-challenging creative learning spaces."
>
> *(Davidson, Prahalad and Harwood, 2020).*

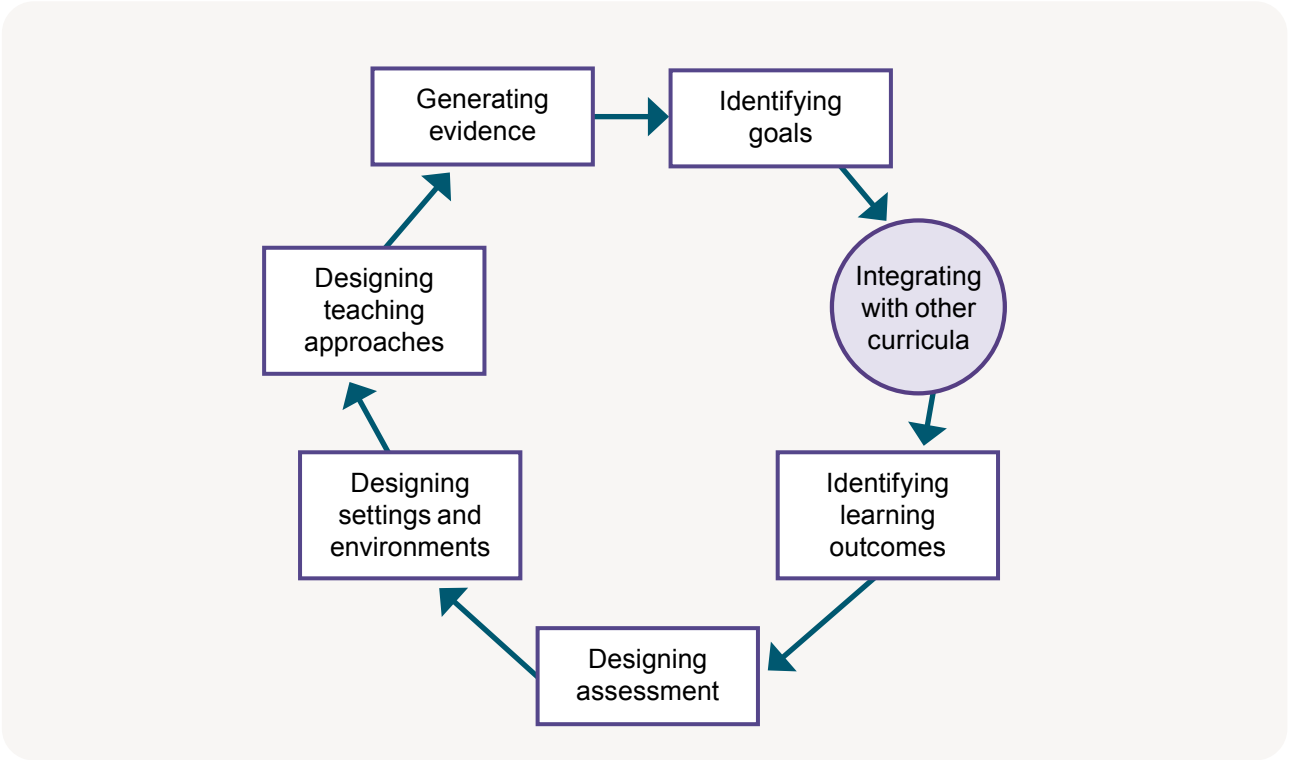
This formidable goal amounts to an education in values and worldview (Birdman, Barth and Lang, 2022; Redman and Redman, 2017; Shephard et al, 2015, 2021). It aims to amend students' prior learning, predispositions, expectations and attitudes, changing their mental models in ways that are more conducive to sustainability. Through this personal transformation it is hoped that students will develop new ways of thinking, acting and being (Advance HE and Quality Assurance Agency, 2021), enabling them to bring about profound and lasting change at the systemic level, beyond their own personal consumer behaviour (Holdsworth et al, 2020). ESD seeks a paradigm-challenging shift in mindset (Backman et al, 2019; Davidson, Prahalad and Harwood, 2020).

However, in their review of transformative learning for sustainability, Rodríguez Aboytes and Barth (2020) describe transformation as superficially conceptualised with a 'buzzword' approach indicative of a fragmented theory. The challenge is that transformation is epistemic – the highest order of sustainability learning and the most elusive (Evans and Ferreira, 2020; Sterling, 2011), although the lower orders of learning (knowledge and/or awareness, changes in beliefs, values, assumptions and ways of doing things) may be present. Moreover, instrumentalising education for systemic change in this way may be more acceptable to academic disciplines where practice is already subject to external standards – engineering, for example – than for others. Tensions may arise "for learners who have not given up their essential freedoms to join the sustainability profession" (Shephard, Rieckmann and Barth, 2019). In all cases this demands careful attention to the relationship between subjective and structural change.

Another way transformation is challenging is that it often entails transgression – contravening the current order. Following from the inertia mentioned earlier, transgression is an implicit goal of ESD. Students are asked to reimagine the world, navigate unsustainable norms and challenge settled approaches, usually while lacking the structural power to effect change. This comes to the fore in workplaces, community settings and partnerships, where others may not be ready to engage fully with proposed changes or may be constrained in their vision. Tensions related to transgression are increasingly acknowledged (Horn et al, 2022).

In many of the publications reviewed, the goals above are implicit rather than explicit, even where there is rich, multi-faceted discussion of ESD. What is clear is that the challenges of ESD are stubborn, and the gap between sustainability concern and sustainability action observed in wider society continues to be reflected in university student outcomes (Pujol and Tomás, 2020; Weinberg et al, 2020). However, compared to the disastrous consequences of persistent unsustainability, the challenges of ESD are preferrable by far. In the next sections we report how these goals have been operationalised as learning outcomes and enacted in assessment and teaching.

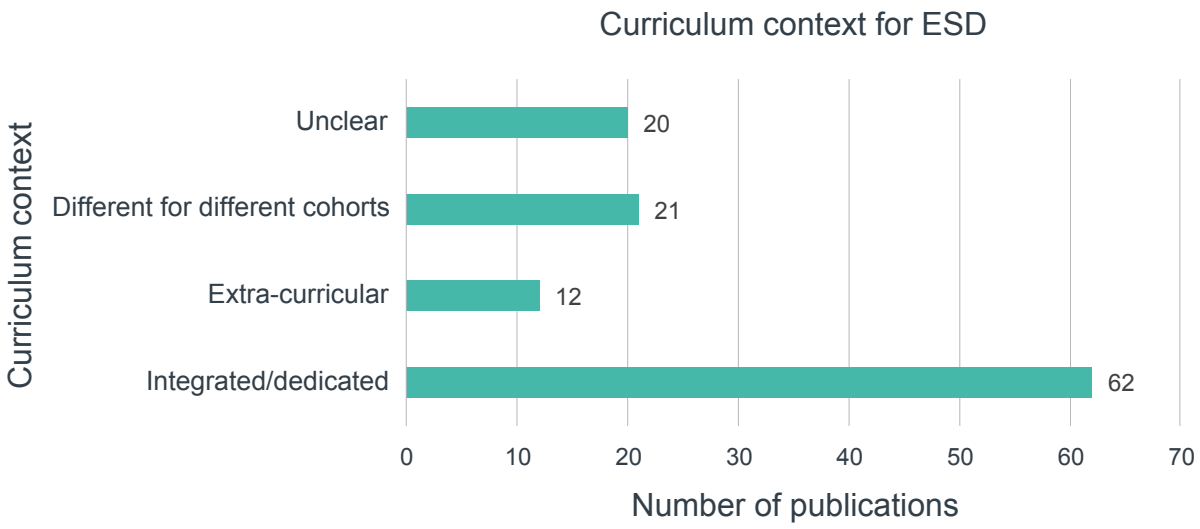
Integrating with other curricula



ESD curriculum design processes are a “blind spot” in the research literature, according to Schweizer, Di Giulio and Burkhardt-Holm (2019), with a lack of clarity about where ESD fits with students’ degree learning. We found that the publications we reviewed often made the context of the ESD obscure. This led us to categorise ESD quite broadly as extra-curricular and embedded, as shown in Figure 5. However, some general principles emerge which we expand on in this section. Students whose degree programmes do not otherwise provide them with ESD – often hard pure subjects such as Maths and Physics – need an extra-curricular (standalone) sustainability course. Since such courses are optional and adjunct, they rarely contribute to the degree, are prone to fall down students’ list of priorities, and consequently are not associated with enduring learning or transformation. In contrast, embedded sustainability teaching takes place within degree programmes, as vertically integrated dedicated streams or horizontally integrated into existing disciplinary teaching. Dedicated sustainability courses or units with their own place in the timetable are typically more straightforward

to design, implement and assess, but horizontal integration is more associated with deep, enduring, connected sustainability learning. The most deeply embedded ESD is designed into the core curriculum and reaches every student. Achieving this depends on institutional drivers such as leadership, professional development opportunities and incentives. Below we describe different approaches to ESD in more detail with alternative terminology and examples.

Figure 5. Curriculum context for ESD in 115 reviewed publications (not included: literature reviews and conceptual publications)



How institutions approach integrating sustainability

Several reviews have explored institutional approaches to incorporating ESD. These shed valuable light on types of integration along with institutional drivers, enables and barriers. We synthesise them in Table 1 and offer some examples in the following sections. In Table 1, integration types 1-5 can be thought of as a continuum where 1 is simpler and cheaper but less effective and 5 is more demanding and resource intensive but more integrative and associated with holistic, enduring learning. The final two, a) and b) can co-exist with any the levels but are more associated with the more integrative levels 4) and 5). Although types 1 and 2 are not generally associated with effective ESD, the examples we have found in the published literature are creative, well designed and maximise the opportunities available within their constraints.

As mentioned, we have not been able to map the publications reviewed to these approaches, since context is frequently unclear.

Table 1. Typology of approaches to integrating sustainability into curricula, drawing on (Mburayi and Wall, 2018; Mokski et al, 2022; Tijsma et al, 2023; Weiss et al, 2021; Weiss and Barth, 2019)

Approach	Characteristics and conditions	Examples
1) Extra-curricular course available to all, not integrated	May be the only sustainability teaching available to some students; requires resource to establish, maintain and promote; may have narrow focus which isolates ESD from disciplinary learning; if appropriate resource, expertise and curriculum design, can deepen disciplinary learning and bring inter- and transdisciplinary encounters; if optional may not signal importance; may not be prioritised by students.	(Cravero et al, 2021; Dike and Ugwuanyi, 2022; Sivapalan, Clifford and Speight, 2016; Vazquez-Verdera et al, 2021).
2) Incorporated into existing curricula	Relatively straightforward to set up; rarely requires institutional backing or permission but is dependent on individual educators; may be narrow, sporadic, limited and downgraded relative to other parts of the curriculum; may be elective and reach smaller numbers; may not signal importance; may be only sustainability teaching available where limited resource exists; can be well-designed and effective within these constraints.	(Aránguiz et al, 2020; Blodgett and Feld, 2023; Sales de Aguiar and Paterson, 2018; Zidny, Laraswati and Eilks, 2021)
3) New dedicated, discipline-specific curricula	May bring greater relevance; may be narrow, limited and adjunct; if optional may not signal importance and may reaches smaller numbers; more resource needed to establish and maintain a dedicated curriculum; can be well-designed and effective within these constraints.	(Boarin and Martinez-Molina, 2022; Foley et al, 2017; Holdsworth and Sandri, 2021; Ødegaard et al, 2021; Richardson et al, 2019; Tomas, Girgenti and Jackson, 2017)
4) Designed into existing disciplinary core curricula	Helps students develop holistic perspectives over time; can reach larger numbers; leadership, expertise and continuity needed; major resource needed to establish and coordinate across disciplinary boundaries, and for CPD; enabled where sustainability is prioritised across the organisation.	(Abd-Elwahed and Al-Bahi, 2021)
5) New cross-disciplinary curricula incorporated into degree programmes	Helps students reinforce and activate disciplinary learning and develop holistic interdisciplinary perspectives over time; can reach larger numbers; requires leadership, expertise and continuity; can be co-created with students, educators from different disciplines and external partners; requires major resource to establish and coordinate across disciplinary boundaries, and for CPD; achievable where sustainability is a strategic goal in the organisation and expertise exists in sustainability, interdisciplinarity and transdisciplinarity.	(Schweizer, Di Giulio and Burkhardt-Holm, 2019; Tijsma et al, 2023)
a) Part of a whole-institution approach	Enables 4), 5) and a); sustainability infuses the entire institution; capacity is developed across all staff groups; sustainability is incentivised; there is consistent commitment to ESD in every area; expertise and capacity in sustainability, inter- and transdisciplinarity exists; co-creation with internal and external stakeholders is standard; requires leadership, resource, coordination and maintenance; achievable where sustainability is a strategic goal and central to the institution's identity.	(Schweizer, Di Giulio and Burkhardt-Holm, 2019; Tamura et al, 2018; Tijsma et al, 2023)
b) Through work with external partners	Can occur at levels 1-5 though likely to be more transformational where integrated at higher levels; is enabled by a); requires resource to establish and maintain partnerships and coordinate the work for reciprocity; brings real-world practice opportunities associated with deep learning and effective sustainability practice; local partnerships may have particular benefits.	(Burden and Sprei, 2021; Earl et al., 2018; Martínez Casanovas, Ruíz-Munzón and Buil-Fabregá, 2022; Martínez-Campillo, Sierra-Fernández and Fernández-Santos, 2019)

Extra-curricular

Also called standalone, isolated or adjunct, these courses are a generic, widely available offering outside degree curricula, typically elective and often without credit. Although extra-curricular courses may be less relevant to students' future career prospects, Mokski and colleagues (2022) recommend making them available in any institution which needs to reach students whose degrees would otherwise give them minimal exposure (typically those studying pure disciplines).

Adjunct and often involving heterogeneous teaching teams, extra-curricular courses required careful design to build their transformational potential. In a business context, lecturers coordinated together to integrate their five courses with an ongoing student competition to produce a business plan for sustainable development (Claro and Esteves, 2021). Consequently, they observed some desirable effects, including students reorienting towards creating shared value (rather than neoclassical) business models. The students also increased their grades, which the authors attributed to improved engagement.

Designing a university-wide, elective programme taught by multiple faculties

At the University of Basel, a team of subject experts and educationalists set out to bring focus, evidence and consensus to the redesign of an elective programme taught across three faculties and available to all students (Schweizer, Di Giulio and Burkhardt-Holm, 2019). Students expected interdisciplinarity along with opportunities to apply their theoretical knowledge but struggled to make connections between disciplines. A redesign team of subject experts, decision-makers and implementers was established, comprising delegate lecturers from the faculties involved. A separate support team of ESD experts generated data and evidence, advising the redesign team on alternative decisions in programme design. The wider group of individual lecturers would be free to make decisions about their own courses, guided by the redesign and support teams.

Through internal and external evidence-gathering, the support team found that the heterogeneity of disciplines, while vital to ESD, brought a bewildering diversity of epistemologies, discourses and practices. Coherence was needed – for lecturers through interdisciplinary consensus-building processes, and for students through explicit connections between elements of the programme. The consequent redesign prioritised integration. It entailed the support team briefing the redesign team, and a workshop for the wider teaching team about interdisciplinary teaching. A common thematic focus was introduced to help students make connections between the individual lectures. A stimulating kick-off event brought all the main lecturers together to demonstrate how different disciplinary perspectives complemented each other in addressing the common focus. A capstone-like unit further guided students in integrating disciplinary knowledge.

Reflecting on the redesign process, the authors observe that the division of labour – educationalists as evidence-bringers and lecturers as decision-makers and implementers – is efficient and fruitful if the data collection integrates perspectives from all stakeholders with contemporary research evidence.

Occasionally, extra-curricular courses are compulsory. The strong service ethos at Amrita University, Kerala means that every student participates in the 'Serve an Hour' programme (Dhivvya et al, 2019). Students are allocated into an interdisciplinary group, visit a local setting to identify sustainability problems, select a relevant aspect of the three pillars, learn about it and teach it to others. Student feedback indicates that they associate 'Serve an Hour' with an improved sense of civic responsibility, an 'education for life', and leadership and teamwork abilities. Alumni are reported to often be involved in community service activities.

In the publications reviewed, few extra-curricular courses contributed to degree credit, though some offered other forms of credit. In the UK, completion may be recorded in the Higher Education Achievement Record (HEAR). Clark and Capps (2020) report offering all students with undeclared majors a project-based learning module which could be the entry point to a certificate in sustainability. When offered for credit to a wide range of students, these kinds of generic courses can be complicated to design and administration. One complication is the operational question of where a cross-institution credit-bearing course's administrative base is (Coops et al, 2015), another is how to design for very diverse prior knowledge, and a third is how to attract students from 'non-obvious' disciplines (Sivapalan, Clifford and Speight, 2016).

Dedicated within a degree programme

Also called concentrated, vertically integrated and bolt-on, this ESD takes the form of dedicated disciplinary streams, courses or sessions within a degree programme.

Professional education, with its multiple stakeholders, makes widespread use of this approach. Reviewing the literature on teacher education (Imara and Altinay, 2021) found that the dedicated course was the most prevalent approach to ESD. A study in nursing (Richardson et al, 2019) found that dedicated scenario-based learning sessions during the degree were associated with improvements in students' self-reported personal sustainability practices and their willingness to challenge unsustainable practices at work. In architecture, Boarin, Martinez-Molina and Juan-Ferruses (2020) identified potentially deep knowledge acquisition from dedicated sustainability teaching. Alongside this, their architecture students requested further integration of ESD into their design studio teaching where they could put it into action, since "if the topic remains something for theory only, it will never become mainstream".

Students do not necessarily welcome dedicated sustainability teaching, even though they are generally positive about sustainability itself. Students from hard, pure disciplines can experience difficulties connecting their objective analytical epistemologies with the more value-driven discussions around sustainability, which deepen students' critical reflection. Unless this is addressed, those students may gain knowledge and competencies without changes in attitudes or intentions to act (Ceulemans and Severijns, 2019). Empathetic alignment between the curriculum and students' motivations and hopes may help here. Computer engineering students became more positive about a compulsory course in sustainability and ethics after it was redesigned to be more relevant to their future careers (Burden and Sprei, 2021). In education, Foley and colleagues (2017) recognised

students' resistance as reflective of the poverty of sustainability thinking in wider society. With this in mind, Novy, Banerjee and Matson (2021) focused their efforts upstream to change society by developing the leadership abilities of learners from any discipline. Through an iteratively developed curriculum, they cultivated each student's competency, agency and identity to prepare to lead sustainability decision-making in complex systems around the world. This kind of identity development may help students to confront stubbornly unsustainable norms.

Integrated within a degree programme

Also called built-in, dispersed or horizontally integrated, this ESD is embedded in the modules of a degree, tailoring the sustainability content and approaches to each discipline's specificity.

Teaching pest control in chemistry

Although applied disciplines are generally thought to be more amenable to embedding than pure ones, Zidny, Laraswati and Eilks (2021) demonstrate otherwise.

Since many educators are free to decide what they do in their timetabled sessions, integration at the level of the individual session is typically easier than at a module or degree level. In Indonesia, chemistry educators designed a session to maintain their students' focus on scientific technology, chemistry content knowledge and argumentation while at the same time developing a pluralistic understanding of social issues in pest control.

Students were introduced to pesticides according to the (dominant) western scientific knowledge system, which included critique. They then completed a worksheet task to identify issues with common pesticides, followed by a debate. Next, they were introduced to a contrasting approach to pest control by the Baduy, a local indigenous community who use solvents from fermented sugar cane to repel, rather than destroy, insects. A second worksheet task required students to balance the requirements of food production and nature, and a third worksheet task required them to use chemistry concepts to explain the relative sustainability of the pesticide DDT and the bio-control approaches of the Baduy.

The authors categorised students' arguments as socio-economic, ethical, ecological or scientific, and found that while ecological and scientific arguments were prevalent, as expected in chemistry, there were large improvements in socio-economic and ethical arguments between worksheet tasks one and two. They concluded that the introduction of multiple scientific worldviews about pest control had prompted students to integrate social, ethical, and philosophical reasoning with their chemistry knowledge.

The local, familiar nature of the indigenous practices strengthened students' engagement. A similar sense of personal connection and relevance may help with transferring this approach into other regional contexts where indigenous communities do not exist, but alternative practices do.

In disciplines where students are learning practical skills and methods, sustainability problems can be incorporated as meaningful, motivating opportunities to put learning into practice. In Accounting, Sales de Aguiar and Paterson (2018) had success with setting students the task of applying their accounting methods and knowledge to the real-world, local problem of their own university's sustainability practices. For International Cooperation students learning research methods, Aránguiz and colleagues (2020) used local sustainability problems as sites of application. In Robotic Engineering, Pujol and Tomás (2020) set an assignment incorporating climate change and discovered that this intrinsically motivated women, a group they were hoping to attract into STEM. Engineering students, if they had sufficient knowledge about the three pillars, were able to use a Sustainability Matrix tool to conduct a holistic analysis of their master's project planning and development (Sanchez-Carracedo et al, 2020).

Confidence on the part of educators is key to integration. This is a particular issue for ESD in professional education such as Architecture or Medicine where many lecturers are practitioners who are not core members of academic staff but have been invited to teach their area of expertise (Boarin and Martinez-Molina, 2022; Walpole and Mortimer, 2017). The challenge here is to develop their holistic understanding of how sustainability is conceptualised and taught across the degree so that the individual parts connect with each other.

Considerations in curriculum design

Some further themes from the literature are set out below.

Learning with external partners is widely discussed (Armstrong et al, 2016; Earl et al, 2018; Hilger and Keil, 2022; Weiss et al, 2021). External partnerships are widely considered the most effective way to transform students' sustainability knowledge, consciousness and intentions into competent sustainability action. We discuss them in more detail in the section 'Designing settings and environments'.

There are calls for intertwining of dedicated sustainability courses and wider degree curricula, in recognition that no single course can meet the needs of every student (Birdman, Barth and Lang, 2022; Boarin and Martinez-Molina, 2022). However, Mokski and colleagues (2022) note a polarisation between the embedded and standalone camps with little complementarity between them. This polarisation may be rooted in different views about whether ESD should be approached as a coherent domain of knowledge or a set of generic competencies (Kuehl et al, 2021), and whether it should be personally oriented to students' behaviour change as consumers, or systemically oriented to mobilising students as agents of change. Yet some of these distinctions blur under examination. For example, Cordero, Centeno and Todd (2020) observe that ESD that addresses students' personal consumer behaviours has an impact on long-term pro-environmental decision-making. This, taken on aggregate, reduces greenhouse gas emissions as effectively as some other more systemic climate change mitigations such as renewables, and also enables students to spread practice by communicating with others about their actions. This anticipated transformation through individualised education for sustainable consumption fits the description of 'Capitalism with a green face', one of the competing pathways to sustainable development identified by Mochizuki and Yarime (2016, 14) and

may have particular impact in relatively prosperous, marketised countries with weaker sustainability protections. However, the broad consensus in the publications reviewed is that individualistic approaches are limited. There is an imperative to overcome systemic threats to sustainability by strengthening sustainability protections. Well-strategised action for this kind of transformation depends on collaboration and connection.

Interdisciplinary collaboration between educators brings holistic thinking to curriculum change (Sivapalan, Clifford and Speight, 2016; Taimur and Onuki, 2022; Tolppanen, Kang and Riuttanen, 2022; Walpole and Mortimer, 2017) along with self-esteem, refreshment, and optimism for the collaborators themselves (Disterheft et al, 2015b). However, bringing multidisciplinary teams together does not inevitably yield interdisciplinarity: this takes facilitation. In their work to identify success factors in these kinds of collaborations, Disterheft and colleagues (2015a, 2015b) emphasise the importance of the participation of a wide variety of stakeholder groups in recognition of the negotiation required to generate transformative knowledge and practices. However, this can be resource intensive. In contrast, facing constraints which prevented this kind of negotiated, deliberative decision-making involving every stakeholder, Schweizer, Di Giulio and Burkhardt-Holm (2019) describe how a small team of ESD specialists carried out data collection from stakeholders and integrated it with contemporary ESD research to inform the decision-making of a programme team of disciplinary specialists.

Scaling up sustainability education in institutions as comprehensive provision is a widespread aspiration. We recorded references to several models, reference frameworks and benchmarking tools for curriculum design and evaluation, but few occurred more than once in the dataset, and none was prevalent. Seeking insights about curriculum change from 133 case studies Weiss and colleagues (2021) identified key drivers and enabling factors. Drivers were opportunities for professional development, incentivisation of ESD, synergies in the way an institution incorporated sustainability into its education, research, campus operations and outreach, and the active involvement of external stakeholders. These were needed for full, redesigned implementation of ESD. Further enabling factors were leadership through strategies, plans and support (though not so strong that it became a barrier) and involvement of internal stakeholders. Also researching curriculum change for sustainability, Weiss, Barth and von Wehrden (2021) identified five key influences: impetus (can be internal or external); communication (informal can suffice where formal is lacking); sense of ownership (needs to be shared internally and externally); collaboration and coalition-seeking among internal and external partners; coordination and synergies among initiatives (to conserve energies).

Student demographics were not strongly present in the publications we reviewed. The regression modelling carried out by Tolppanen, Kang and Riuttanen (2022) after a holistic ESD programme indicated that gender has an independent role predicting the changes in knowledge, worldview and willingness to take action. Women in their study indicated willingness to change their lifestyles in the light of new knowledge, while men did not. They conclude that to achieve the hoped-for transformation in all students rather than simply activating the most willing ones, holistic approaches should account for personal characteristics such as gender. Felgendreher and Löfgren (2018) and Remington-Doucette and Musgrove (2015) reached similar conclusions. In robotic engineering, Pujol and Tomás (2020) found that an assignment incorporating climate change intrinsically motivated women, which

they considered a promising approach to attracting more women into STEM. Ødegaard et al (2021) implicated maturity in years and experience in student teachers' abilities to adapt to the frustrations of sustainability learning. Remington-Doucette and Musgrove (2015) observed that students starting an undergraduate degree are prone to dichotomous thinking but develop an appreciation of context as their studies progress. This has implications for the timing and preparation for the most challenging elements of ESD, such as high stakes inter- and transdisciplinary project work.

Diverse paradigms and frames of reference exist for sustainable development, and therefore for ESD. They define the problems differently and identify different solutions. Drawing on a typology set out by the UN Research Institute for Social Development, Mochizuki and Yarime (2016, 14-15) have set out five competing worldviews (Figure 6).

Figure 6. Five competing worldviews for sustainable development (after UNRISD, 2012; Mochizuki and Yarime; 2016; 14-15)

Worldview	Capitalism with a Green Face	Sustainable Development as Defined by the UN	Social Economy	Limits to Growth	Sustainable Cities
Views of sustainability	Economic growth creates capacity for sustainability.	Strong states and institutions bring governance mechanisms.	Rebalancing global inequalities and restructuring capitalism brings justice.	The impossibility of limitless growth given the limited ecological capacity of Earth.	Cities as systems with design considerations for utilities, waste, and construction.
Approach to sustainability problems	Crises in the system to be resolved through top-down crisis management, (rather than crises of the system).	Ongoing fragmentation and blind spots around global institutional governance require top-down intervention.	Capitalism as the primary driver of injustice. Bottom-up global coalitions to reject business as usual and refocus on ethics and justice.	Top-down enforcement; degrowth or no-growth and alternatives measures to GDP. Bottom-up valuing nature.	Sustainable investment and design. Bottom-up and top-down multi-stakeholder approaches.

The difference in worldviews and directionality of their proposed approaches – top down, bottom up, combinations of the two – prompts attention on which perspectives are normalised and which are absent or marginalised. This is important in the context of collaborative and interdisciplinary work where students need to navigate different perspectives. It is also important because ESD approaches may be attempted in very different regional and social contexts from those in which they originated, and this requires close engagement with local worldviews and systems. Where such approaches are imported without due engagement with these local realities, an education-reality gap opens up. Demssie and colleagues (2020) describe how taking western worldviews for granted has marginalised indigenous and local knowledge (ILK) in Ethiopia. The individualist assumptions originating in western contexts failed to connect with the collectivist worldview prevalent in the Ethiopian context. In response to such breakdowns in engagement, Serpa and Sá (2019) call for a more critically reflexive stance towards knowledge, which they express as a shift from 'science for society' to the more mutual, reciprocal 'science with society'. In higher education, involvement with wider society often takes the form of external partnerships in community settings. However, to genuinely integrate perspectives beyond dominant scientific knowledge, a bi-directionality – genuine mutuality – is needed, which Zidny, Sjöström and Eilks (2020) describe as "two-eyed seeing" and Druker-Ibáñez and Cáceres-Jensen (2022), as,

> "…disruption in the dynamics of knowledge legitimation and social hierarchies associated with the knowledge power relationship that is part of peoples' common sense and daily practices, both in formal education and community settings."

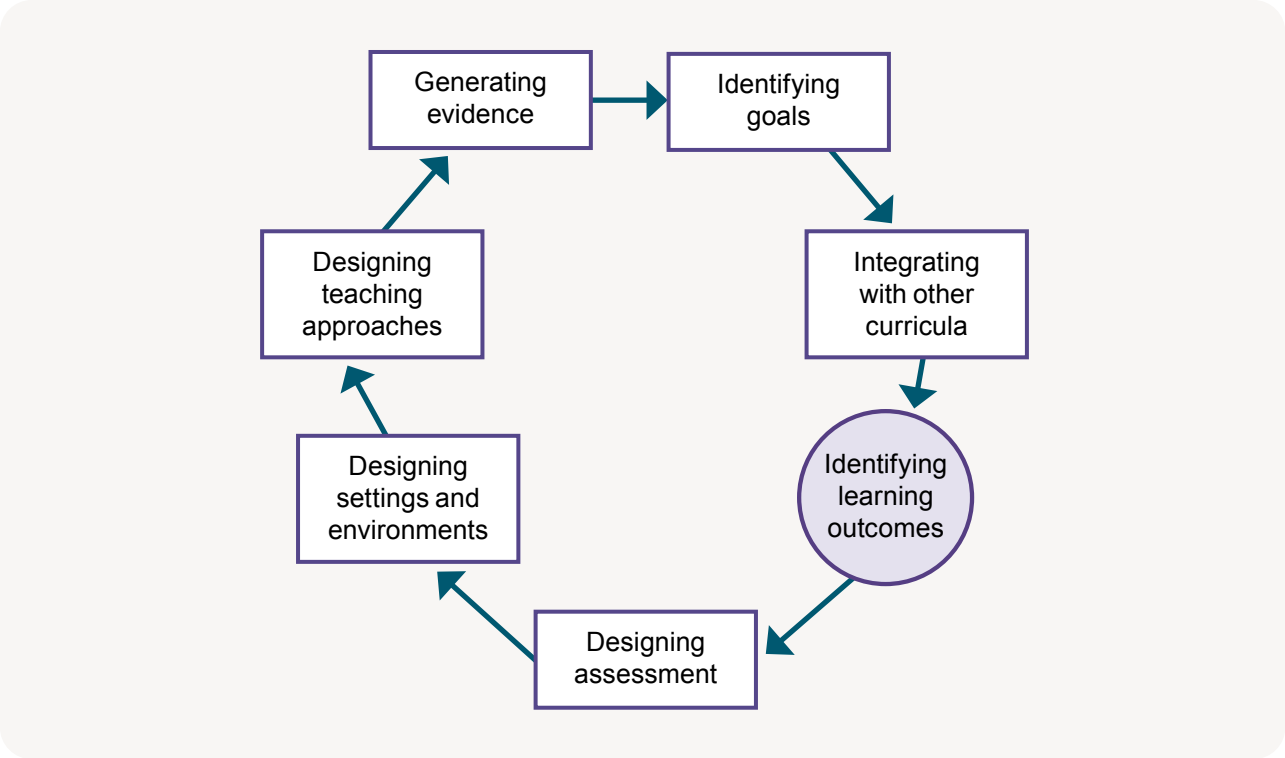
Introducing different worldviews is delicate because it can provoke resistance if received as a corrective. The section 'Integrating with other curricula' includes more detail about how maintaining a focus on disciplinary learning can give students an analytical framework for encountering different worldviews (Zidny, Laraswati and Eilks, 2021).

There are synergies as well as contrasts between worldviews. In their article on Islamic sustainable development theories, Qatawneh and Al-Naimat (2022) emphasise pluralistic thinking, holism, human beings as "the axis of change", "hypothetical and imaginative purpose-oriented thinking", and "the ability to visualise possible events, figure out ways for their containment and develop solutions to them". It is tempting to fit these aims to the UNESCO terminology as interdisciplinarity, systems thinking, strategic thinking, future thinking, and normative competencies. However, Druker-Ibáñez and Cáceres-Jensen (2022) caution against trying to incorporate diverse viewpoints into a dominant one without exploring them carefully from the perspective of their own knowledge system. They emphasise that participatory methodologies are needed for partnerships where there are different frames of reference.

There are implications for academic freedom and agency where ESD is compulsory. Shephard (2021) points out that a policy of applying ESD to all students is in contrast to current liberal approaches in higher education where students decide for themselves what they wish to learn and think, and academics decide what they wish to teach. This potential conflict is likely to be felt more keenly by some disciplinary identities than others, and he identifies critical thinking as the way to

resolve it. At the same time, he recognises that critical thinking is an unruly competency that defies predetermined learning outcomes. With other authors, he also explores a direct comparison between sustainability and common-sense priorities such as democracy, ethics or academic honesty. These are routinely taught in higher education without any worries about indoctrination (Shephard, Rieckmann and Barth, 2019). We revisit this in the section on 'Values'.

Identifying learning outcomes



In many educational settings, intended learning outcomes are the bases of curricula and the way the ESD goals above are operationalised for teaching and assessment. The publications we reviewed are from diverse academic fields, with distinct disciplinary learning outcomes and different sustainability orientations. However, taken together, their learning outcomes fall into three main categories: knowledge, competencies and values. When integrated, these three enable a fourth, more tacit learning outcome, readiness to act. The first two – knowledge and competencies – are more readily formalised as learning outcomes, while the last two are more likely to be implicit because they are emergent, personal and very hard to assess. However, the review suggests that to achieve the transformative goal of ESD, students need all four. The formalised learning outcomes lend shape and scope to what students should focus on at their current level of learning. Given the tendency to formalise only the learning outcomes that will be assessed, educators need consider how to bring the more aspirational learning outcomes – values and readiness to act – into the ethos, culture and practices of the curriculum.

A lack of clarity on learning outcomes

In the publications reviewed, learning outcomes are often unspecified (Probst, 2022) so it is not easy to discern the competency-related learning outcomes set out in the (Advance HE and Quality Assurance Agency, 2021) guidance, nor learning outcomes related to knowledge (the three pillars set out in the Sustainable Development Goals) or values (for example the ability to critically reflect on premises and assumptions). The literature hints at reasons for this. We have mentioned the emergent and unruly nature of transformative learning outcomes such as critical thinking and intention to act, making them hard to pin down or assess. There is also the question of relevance. In some disciplines and some local settings, the relevance of some of the SDGs may not be obvious (Claro and Esteves, 2021; Sanchez-Carracedo et al, 2021). The UNESCO competencies are not reliable indicators either, since as Aznar et al (2016, 435) note, they are not unique to sustainability and can be found among the general competencies of the majority of degree programmes without any reference to sustainability. For example, engineering education has evolved towards contextualising ESD learning outcomes, rather than holding them apart as scientific-technical knowledge. This means they may be very well integrated with existing degree learning outcomes and hard to discern (Holgaard et al, 2016; Sanchez-Carracedo et al, 2021) unless you are a subject expert familiar with the assessment rubric descriptors (Abd-Elwahed and Al-Bahi, 2021). Finally, because of the convention for only listing assessed learning outcomes, it may be the case that only learning outcomes to be "demonstrably achieved" through assessment are formalised, while those that are "more aspirational in character", such as the UNESCO competencies, may be unassessed and therefore implicit (Shephard, Rieckmann and Barth, 2019). In summary, it is rarely clear from the publications we reviewed what learning outcomes exist or to what extent ESD is present but hidden.

Nevertheless, effective ESD depends on integrating knowledge, competencies and values (Ceulemans and Severijns, 2019; Shephard, Rieckmann and Barth, 2019). We examine each of these learning outcome categories below and draw some connections with students' readiness to take action.

Knowledge

As we have mentioned (see 'Inclusion criteria'), scientific sustainability knowledge alone – for example, about ecology, waste or water management, or the circular economy – is not ESD and is rarely transformative (Dlouhá et al, 2019; Earl et al, 2018; Holdsworth and Sandri, 2021; Tolppanen, Kang and Riuttanen, 2022). However, sustainability knowledge has been observed to bring a more environmentally friendly mindset, feelings of being part of nature and co-evolving with it, appreciation and conservation of nature, a locus of control, and a sense of being a critical stakeholder (Druker-Ibáñez and Cáceres-Jensen, 2022; Kinoshita et al, 2019; Merritt, Hale and Archambault, 2019). As such, sustainability knowledge awakens values and gives meaning to competencies. Knowledge is also essential for sustainable decision-making (Blodgett and Feld, 2023; Cordero, Centeno and Todd, 2020; Mintz and Tal, 2018; Redman and Redman, 2017). Teacher education illustrates the extent of the complexity here: student teachers must contend with formidable layers of learning to first understand sustainability content, then internalise values and master competencies and pedagogies

so that they can, in turn, embed ESD into the teaching they design for their own students, tailoring it for different age groups (Brandt et al, 2021; Foley et al, 2017; Ødegaard et al, 2021; Weinberg et al, 2020).

Educators need to direct their students' attention. Learning outcomes delineate which scientific sustainability knowledge needs to be learned, so that its otherwise vast scope does not become a disorienting barrier to learning (Brandt et al, 2021). Here the publications reviewed emphasise the importance of a common thread, such as food, soil, waste, energy or pollution, to enabled focus (Hermann, Bossle and Amaral, 2022; Schweizer, Di Giulio and Burkhardt-Holm, 2019; Tamura et al, 2018). Students are also likely to need the support of educators to hold the three pillars (economy, ecology and society) in balance, since they tend to compete for priority and potentially weaken each other. For example, Affolderbach (2022) observed students struggling to develop sustainable business models outside the dominant economic growth paradigms, defaulting to non-profit or charitable projects. Sherman and Burns (2015) advocate for critical theory alongside subject knowledge to catalyse shifts in perspective.

Competencies

Oanh (2018) describes competency as "a complex combination of knowledge, skills, understanding, values, attitudes and desire which lead to effective, embodied human action in the world, in a particular domain". The publications reviewed draw on, but often under-conceptualise, many overlapping but distinct competency lists and frameworks (Probst, 2022; Sandri, Holdsworth and Thomas, 2018a). Competencies are sometimes grouped together according to whether they represent ways of thinking, practising or being (Advance HE and Quality Assurance Agency, 2021; Wang, Sommier and Vasques, 2022). One set of eight competencies in widespread international use is that proposed by UNESCO (Advance HE and Quality Assurance Agency, 2021; UNESCO, 2017; Evans and Ferreira, 2020). They are set out in Table 2.

Table 2. Competencies for sustainable development (Advance HE and Quality Assurance Agency, 2021; UNESCO, 2017)

Competency	A student with this competency can:
Systems thinking competency	+ recognise and understand relationships + analyse complex systems + think of how systems are embedded within different domains and different scales + deal with uncertainty.
Future thinking competency	+ understand and evaluate multiple outcomes + create their own visions for the future + apply the precautionary principle + assess the consequences of actions + deal with risks and changes.
Critical thinking competency	+ question norms, practices and opinions + reflect on one's own values, perceptions and actions + take a position in the sustainable development discourse.
Strategic thinking competency	+ collectively develop and implement innovative actions that further sustainability at the local level and further afield.
Collaboration competency	+ learn from others + understand and respect the needs, perspectives and actions of others (empathy) + deal with conflicts in a group + facilitate collaborative and participatory problem solving.
Integrated problem-solving competency	+ apply different problem-solving frameworks to complex sustainable development problems + develop viable, inclusive and equitable solutions + utilise appropriate competencies to solve problems.
Self-awareness competency	+ reflect on one's own values, perceptions and actions + reflect on one's own role in the local community and global society + continually evaluate and further motivate one's actions + deal with one's feelings and desires.
Normative competency	+ understand and reflect on the norms and values that underlie one's actions + negotiate sustainable development values, principles, goals and targets, in a context of conflicts of interests and + trade-offs, uncertain knowledge and contradictions.

The sustainability competencies in Table 2 are not specific to sustainability and can be found in many degree programmes. This apparent genericness is a potential strength since they are likely to be accepted by educators across a wide range of disciplines. Yet this acceptability is also a potential weakness since it does not communicate the urgency of change, nor signal very strongly that to meet the challenge posed by unsustainability, the competencies need to be firmly oriented to sustainability content and action. By comparison, the European Sustainability Competence Framework known as GreenComp (Bianchi et al, 2022) foregrounds competencies which are distinct to valuing sustainability, and which emphasise individual, political and collective action in response to intensifying emergencies. GreenComp is visualised in Figure 7.

Figure 7. Visual representation of GreenComp (Bianchi et al, 2022, 16)

The UNESCO and GreenComp frameworks are broadly congruent, with slightly different emphases on reflection and action. They share a number of competencies, either unambiguously, as with ‘Systems thinking’ and ‘Critical thinking’, or implicitly as with GreenComp’s ‘Supporting fairness’, reflected in UNESCO’s reining in of one’s own desires and equitable problem-solving. Distinct to GreenComp are ‘Promoting nature’, which has no counterpart in UNESCO’s competencies, ‘Adaptability’ which lends more urgency to UNESCO’s ‘Systems thinking’ and ‘Strategic thinking’, and ‘Political agency’ which focuses several UNESCO competencies on operating the levers of power at the highest level. GreenComp is more overtly focused on sustainability and transformation while UNESCO’s framework may at first appear unremarkable and consequently acceptable but may require similar amounts of effort to orient the competencies on sustainability.

Most authors whose work we reviewed referred to at least one competency as a learning outcome. The review by Algurén (2021), which focused on the UNESCO competencies, found that self-awareness normative and future thinking competencies were least addressed. Most prevalent were systems thinking, problem-solving, critical thinking and collaboration. Other competencies (strategic, future, self-awareness and normative) were less addressed or more implicit. Competencies may not be explicitly formalised as learning outcomes at all but may exist in assessment rubrics (Abd-Elwahed and Al-Bahi, 2021; Holgaard et al, 2016; Sanchez-Carracedo et al, 2021). In the publications reviewed, competencies are unevenly represented.

Brandt and colleagues (2019) caution against a one-shot approach to competency development, advocating instead for a recurring, systematic and holistic process for the duration of a course. The publications we have reviewed here send a clear message that gaining ESD competencies is catalysed by opportunities to practice them on real-world problems involving external stakeholders or partners (Armstrong et al, 2016; Schweizer, Di Giulio and Burkhardt-Holm, 2019; Warwick, Wyness and Conway, 2017). Davidson, Prahalad and Harwood (2020) emphasise the importance of a collective or collaborative teamwork approach to tackling sustainability problems "because, as numerous resilience theorists argue, solving such problems requires coordination across boundaries of different kinds and cooperative effort from all affected by a particular problem". In the section 'Teaching competencies' we return to competencies and how they can be developed.

Values

One way to think of values is as the difference between sustainability awareness and sustainability concern. Although most definitions of competencies assume values by default, this literature suggests that they need a distinct focus, particularly when it comes to assessment (Sandri, Holdsworth and Thomas, 2018b). Probst (2022) observes that values are relatively well conceptualised, for example drawing on Theory of Planned Behaviour. However, the hoped-for development of values is rarely inscribed in formal learning outcomes. While it is hoped that they are developed, values cannot be taught and are hard to assess. For example, Birdman, Barth and Lang (2022) identify resilience, self-esteem and self-concept as values essential to changing one's mind, which can be a profoundly unsettling or demoralising experience. These human states (which we revisit in the section 'Difficulties with ESD assessment') evade academic measurement, and it is not clear that they should be measured at all. Shephard, Rieckmann and Barth (2019) advocate for separating "learning outcomes that are to be demonstrably achieved from those that are more aspirational in character", signalling to students what will and won't be assessed.

The relationship between individual values and structural power is important. Davidson, Prahalad and Harwood (2020) caution against an excessively individual focus since sustainability problems tend to defy individualistic solutions. However, clearly some careers have a greater power over, say, pollution, waste or emissions, than others, and there is a case for bringing personal responsibility into sharper focus in the academic disciplines that feed those professions (Boarin, Martinez-Molina and Juan-Ferruses, 2020; Chen, Jeronen and Wang, 2020; Mburayi and Wall, 2018). Moreover, a personal, philanthropic emphasis may be valorised in some societies, irrespective of structural power (Dhivvya

et al, 2019). Several authors report that incorporating individual values and responsibilities into students' critical reflection on knowledge can catalyse transformative learning in a way that knowledge and competencies alone do not (Dlouhá et al, 2019; Dziubaniuk and Nyholm, 2021; Felgendreher and Löfgren, 2018; Sherman and Burns, 2015). Values are key to the transformation which engages knowledge and competencies in action, but they are not an inevitable consequence of developing sustainability knowledge or competence (Braßler and Sprenger, 2021).

Nevertheless, there remains what Probst (2022) calls a paradigmatic divide between "scholars who assume that cognitive and affective outcomes relevant to sustainability should be taught and assessed … and those who have conceptual and ethical concerns about whether higher education can and should tell students what to believe". Addressing this concern about academic freedom, Shephard (2021) judges that deep, critical independent thinking is required to bridge this divide, but also that it is in tension with fixed learning outcomes. Analysing this tension further, Shephard and two other leading contemporary thinkers in ESD (Shephard, Rieckmann and Barth, 2019) read and discussed key ESD literature together. They discovered,

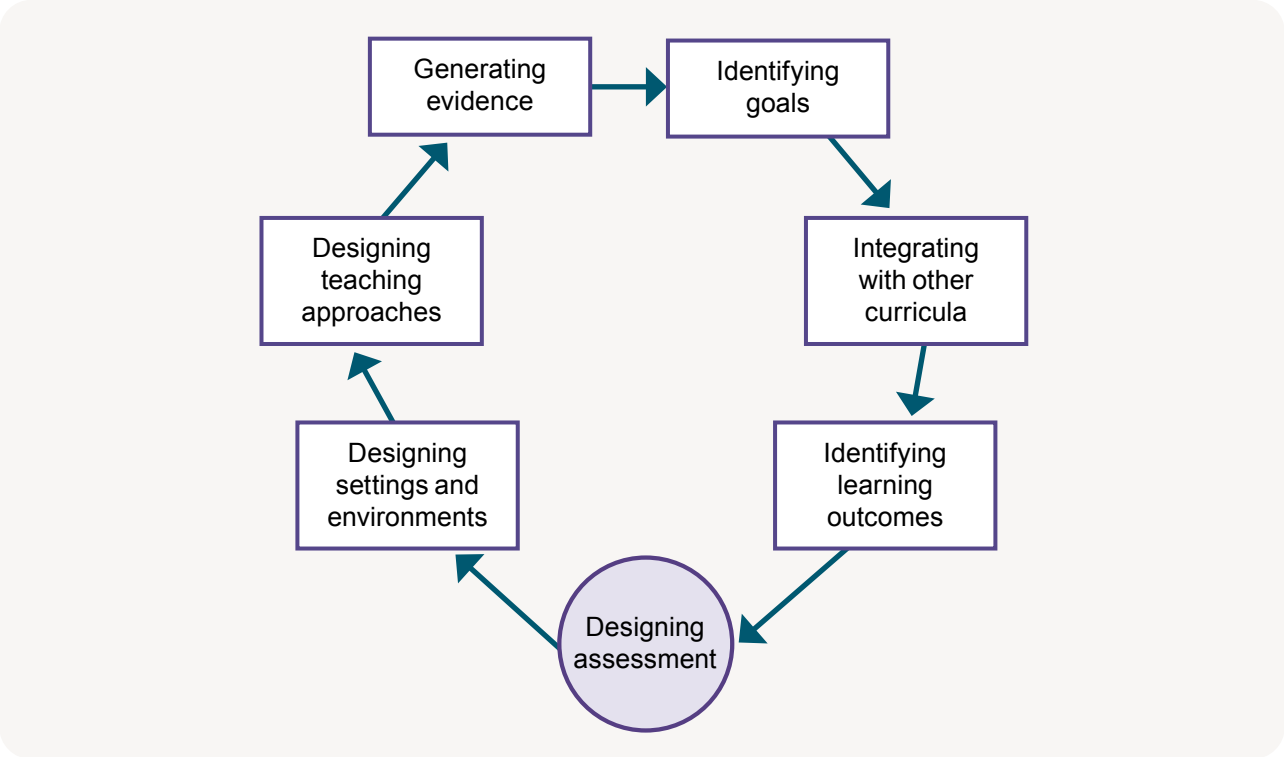
> "…substantial internal contradictions … relating to a desire to support learning in an open and enquiring manner, respectful of the essential freedom that all would wish to afford to learners, and the requirements of specifying, in relatively precise terms, the knowledge, skills and attitudes that learners should acquire."

Recognising that learners within professions, in particular, are already used to overt values education according to the standards of their profession, they speculate that 'sustainability' may be comparable to 'honesty' or 'democracy', both of which are taught without concerns about indoctrination. In this sense sustainability is "not to be the product of learner self-determination, but students' decisions within the concept of sustainability (such as how to achieve it) may be the product of learner self-determination" (our emphases). In other words, there can be freedom to interpret, critique and change sustainability practices but not freedom to reject sustainability itself.

Readiness to act

The overarching ESD goal of social transformation depends on students' readiness to act on the knowledge, competencies and values above. However, the gap mentioned earlier between sustainability awareness and sustainability action interferes with this (Braßler and Sprenger, 2021; Pujol and Tomás, 2020). Recognising this, the most insightful literature we reviewed takes a holistic approach to formulating learning outcomes that stimulate action. Sidestepping the debate about whether ESD learning outcomes are better conceptualised as 'competencies' or 'capabilities', Shephard, Rieckmann and Barth (2019) comment that in general usage across languages, the terms 'competency' and 'capability' have broadly similar meaning – but they both need to be supplemented with the term 'willing'. This illuminates the importance of values, without which knowledge, competencies and capabilities are all likely to remain inert (Dlouhá et al, 2019; Weinberg et al, 2020). Neither knowledge nor competencies inevitably bring this willingness, which is why ESD needs to be an education in values.

Designing assessment



This section is concerned with how students are required to demonstrate that they have achieved the learning outcomes introduced above (values, knowledge, competencies, readiness to act). This complexity demands a holistic approach to assessment that makes it difficult to design. Over the timeframe of our review, we found little development to address conceptual clarity or generate new tools, and only a few in-depth accounts of designing assessment of sustainability learning (elaborated below) though more discussion of difficulties. A recent review concluded that "[r]esearch on assessment in sustainability (science) education appears to likely be in its emergent growth phase, trailing the pattern of research growth in sustainability science by about 15 years" (Redman, Wiek and Barth, 2021). In this section we introduce some examples of assessment approaches that shed light on holistically assessing different learning outcomes.

Taken together these have the following implications. Posing dilemmas based on real-world cases or scenarios can assess students' awareness and responsibility more deeply than self-reported perceptions (though there is no guarantee that students' responses will be reflected in their future practice). If assessing students' roles in external partnerships, it may be helpful to include the partners, though this would also require them to be more closely involved with the course. Concept maps lend themselves to assessing interdisciplinary learning because they bring insights into students' mental models. Rich, authentic modes of communication with notional audiences such as presentations, pitches, or designing food labels can allow students to communicate academic ideas while drawing on sustainability competencies such as normative competency.

Difficulties with ESD assessment

The kind of critical, transgressive and outward-facing work that transformative ESD demands often prompts a rethink of established forms of assessment (Birdman, Redman and Lang, 2021; Dziubaniuk and Nyholm, 2021; Shephard, 2021). The holistic nature of sustainability learning means that where ESD is embedded, assessment criteria need to be integrated with those of the existing disciplinary assessment. There has been much discussion in recent years about more authentic forms of assessment, but also how current assessment approaches are often fixed, longstanding and hard to change (Cicmil, Gough and Hills, 2017).

Assessment methods strongly influence the knowledge, skills and beliefs students bring to that assessment (Pruett and Weigel, 2020). Where assessment methods are misaligned from their intended learning outcomes, this interferes with students acquiring and demonstrating their learning (Brandt et al, 2019; Holdsworth et al, 2020; Warwick, Wyness and Conway, 2017). Assessors may observe students successfully developing competencies, but find that the same students lack the discourse to describe those competencies in a reflective statement, defaulting to what they learned about rather than how they themselves were transformed (Holdsworth and Sandri, 2021). However, some less desirable forms of assessment endure not for educational reasons but because of resource constraints.

Assessing internal cognitive processes is problematic and established methods are scarce (Redman, Wiek and Barth, 2021). There is some dissatisfaction with prevalent measures of sustainability science learning, which are perceived to be over-reliant on scaled self-assessment (Birdman, Wiek and Lang, 2022; Redman, Wiek and Barth, 2021). This kind of self-reported learning has validity problems because it is affected by self-concept and self-esteem and is often discrepant from observed measures of learning (Birdman, Barth and Lang, 2022; Yoon et al, 2016). Shephard (2021) remarks:

> "Enlightened educators might ask if self-reported change could be a sufficient measure of learning gain in HESD, and if so, why is it not similarly valued in other contexts. Just imagine how many examinations and assignments we could dispense with if our learning gains could be, more generally, defined by self-reported change!"

Shephard and Egan (2018) also caution against incentivising performative tendencies when it comes to assessing values, attitudes and behaviours. Valid, reliable approaches are needed which eliminate social desirability effects.

It is not always clear what is being assessed. There is a need to help students internalise the concepts. Shephard, Rieckmann and Barth (2019) call for terminological clarity in how ESD outcomes terms, such as skills, literacy, competencies or capabilities, are used. They attribute the slow progress of ESD towards its objectives to widespread miscommunication or misunderstanding of basic concepts (which they refer to as 'conceptual stretching'). In the context of teacher education Imara and Altinay (2021) make a similar call for clarity. The work of Gulikers and Oonk (2019) on developing a rubric is helpful here, and we expand on it below in 'A boundary-crossing rubric to assess transdisciplinary learning'.

Concept maps

Concept maps consist of concepts related to a central topic, connected by labelled links, resulting in a structure which can be hierarchical or mesh-like. Concept mapping allows students to show how they connect concepts in a way which more closely represents their mental models than linear forms such as essays, and is more visually immediate. The visual nature of concept maps also makes it possible to compare students' mental models before and after a period of learning, and some software makes it possible to quantify the change in complexity (Pruett and Weigel, 2020).

Concept mapping to assess learning gain

Biology students at Georgia Institute of Technology, USA carried out a fortnight of fieldwork monitoring a local stream, contributing data to a wider community stewardship initiative (Pruett and Weigel, 2020). The aim of this activity was to connect students' scientific knowledge with the needs of the community. Before and after the activity they were assessed with a concept mapping task. The authors selected concept mapping because it allowed them to assess learning gains by showing how students differently used and integrated concepts before and after the learning activity.

They analysed the concepts students used and the structural complexity of the maps (how students connected the concepts), looking for an integration of concepts from multiple disciplines. They found that ecological concepts were dominating the social concepts students also needed to learn. The structural elements of the maps revealed that although the students accreted new knowledge, this had brought little or no reconstruction of knowledge structure – in other words, the knowledge was additive and there was no accompanying change in the hierarchies. The authors attribute this to the short duration of on-site work and proposed extension activities such as case studies analysing water policies.

Although concept mapping allowed students to demonstrate connected conceptual knowledge, and revealed limitations in knowledge, the authors observe that it did not readily invite students to include the human dimensions of those concepts. Noting that students' reflective statements elicited more comments about these human aspects, they emphasise that assessment approaches influence the kinds of knowledge students bring to them.

Dilemmas, cases, vignettes and scenarios

Self-reporting about values and behaviour tends to be influenced by social desirability bias. Sandri, Holdsworth and Thomas (2018b) set out to design an assessment of graduates' environmental awareness and social responsibility in a way which would surpass respondents' general self-reported perceptions about their own capabilities. The authors aimed to feed the data into curriculum renewal in property, construction and project management at RMIT, Australia. Recognising the importance of pitching the problem scenarios as neither too easy nor too hard, but sufficiently complex to give students the freedom to explore and weigh up different solutions (Sonnleitner, König and Sikharulidze, 2018), they involved graduates in designing and piloting vignette and scenario questions which would efficiently allow respondents to demonstrate their knowledge. The questions asked respondents to relate the three pillars (economics, ecology and society), appraise and critique context-appropriate sustainability measures, and take a position on a sustainability dilemma. Three of the questions assessed the level of responsibility and leadership that graduates were inclined to take; one assessed how well graduates can recognise systemic interconnections; a fifth (which needed refinement), how well graduates could appraise the appropriateness of different sustainability measures. A sixth question asked respondents where they got the information to respond to the previous questions. The authors developed criteria based on the institution's graduate attributes. They were aware of a possible knowledge-action gap since, although vignettes and scenarios are an improvement on self-reporting, there is no evidence that responses reflect the respondents' future judgements and behaviour. This illustrates one of the major challenges in assessing sustainability mentioned earlier.

Case studies were selected as the most viable approach available to assessing systems thinking and normative, strategic, anticipatory and interpersonal competencies of sustainability for Business students at Arizona State University, USA (Remington-Doucette and Musgrove, 2015). Before and after the semester, students answered the same 11 questions about two case studies. In the interim they took a problem-based course incorporating key concepts, real world challenges and complex adaptive systems theory. Through this case study assessment, the authors were able to discern improvements across competencies and how these were affected by age, gender and major. They underline that students don't come to sustainability as blank slates but bring their own prior knowledge and social conditioning. One of their conclusions is the importance of ensuring that no single gender perspective dominates ESD, since this makes attainment gaps more likely.

A dilemma was posed to students in the School of Business, Economics and Law at the University of Gothenberg, Sweden (Felgendreher and Löfgren, 2018). It was intended to stimulate students' reflection on social norms and their individual responsibilities as consumers, citizens and future decision-makers. During a compulsory extra-curricular 'Sustainability Day', they were asked to judge the social appropriateness of each of three possible responses to a moral dilemma about a manager facing a supplier with sub-standard working conditions. To incentivise students to stay orientated to social appropriateness rather than their own opinion, the authors told them that, if their response matched the majority response of other students who had not experienced Sustainability Day, they would have the chance to win a voucher. Like the Arizona State example above, the authors

discovered gender differences and disciplinary differences. When asked to reflect on their individual responsibility in a moral dilemma, female students perceived inaction as less socially acceptable than their male counterparts. The authors also discovered disciplinary differences.

Assessing interactions between students and external partners

The influence that assessment exerts on learning is well known and needs to be focused on the desired learning. However, where students work with external partners, learning can seem obscure, ambiguous, open-ended and particularly complex to assess.

A boundary-crossing rubric to assess transdisciplinary learning

Educators in a Dutch life sciences context were struggling to anticipate and assess the kinds of learning outcomes students were gaining from their collaborations with external stakeholders (Gulikers and Oonk, 2019). Without clear assessment criteria, students were not being challenged to work and communicate effectively across different stakeholder practices and perspectives and develop the agency to bring about transformation.

The authors addressed this by iteratively designing and refining a rubric to assess these projects. Drawing on a boundary crossing framework, they identified four processes of successful transdisciplinary learning with external partners:

1. Identification of the expertise and perspectives of all stakeholders involved in the problem
2. Coordination or organise and facilitate effective collaboration
3. Reflection to incorporate other stakeholders' perspectives
4. Transformation to co-create new knowledge and sustainable practices around the boundary.

Workshops with students and stakeholders and a culminating questionnaire for students at the end of their projects yielded concrete examples of successful boundary crossing. The authors synthesised their findings into criterion reference statements in a 'Boundary Crossing Rubric'.

In the iterative rounds of evaluation and revision that followed, life sciences educators fed back enthusiastically. Some said the rubric gave them a language to name practices that neither they nor their students had been able to put into words before. Some saw the potential for self-assessment, and one intended to use it as a starting point for curriculum redesign. Environmental science educators trialling the rubric with current students said it enabled deeper discussions about students' roles as collaborators. As with any assessment criteria, students struggled to understand the concepts in the rubric, but their final reflections about what they learned from the collaborative projects were observed to be more specific and diverse than those of previous cohorts.

Hilger and Keil (2022) recommend closer collaboration with external partners as part of the assessment process, incorporating their reflections on the benefits of the collaboration alongside students'. Earl et al (2018) discussed grading as an extrinsic motivation for collaboration and learning, noting that while some students valued non-traditional rewards such as city recognition, a hug from the mayor, networking, community gift vouchers and personal growth, others resisted this non-traditional approach to credit, having been schooled to rely on extrinsic motivations and rewards.

Presentations, posters, plans and pitches

Presentations, posters, plans and pitches are established forms of assessment, individually and in groups, and widely considered as well-suited to demonstrating a range of sustainability learning outcomes. For example, students of Sustainable Management produced a group poster (Warwick, Wyness and Conway, 2017); Accounting students gave a group presentation about the sustainability practices of their own university (Sales de Aguiar and Paterson, 2018). International Marketing students produced a company analysis and business plan (Dziubaniuk and Nyholm, 2021); students on an interdisciplinary History and Food Systems course designed a sustainable food label that integrated human and environmental wellbeing (Blodgett and Feld, 2023); interdisciplinary groups in a university-wide course designed an exhilarating range including an insect hotel, a school yard, a film, a game and a poster (Braßler and Sprenger, 2021). However, in the publications reviewed these assessment approaches are rarely the central consideration and are mentioned without much elaboration on scaffolding or assessment criteria.

Affolderbach (2022) described one case in more detail. She facilitated her Geography students of green economy to self-allocate to project groups according to interest rather than affinity, and convened a 'dragon's den' style panel to give expert feedback on students' pitches. Students used a method ('business model canvas') to organise ideas. Outward facing, multimodal assessments such as these are often used to assess systems thinking and problem-solving competencies in inter- or transdisciplinary settings, which we define in the section 'Designing settings and environments'. In transdisciplinary settings involving external partners, the partners may be involved in the assessment as they were with Tourism students' group presentations, which was a factor which energised students' work (Oxenswärdh and Persson-Fischier, 2020), though none of the publications we reviewed expanded on how to do this for credit-bearing assessment.

Written assignments

Written assignments were prevalent in the publications we reviewed. Genres – generally mentioned without elaboration – included: in Built Environment, reports about students' personal ecological footprints, and reviews of research articles (Holdsworth and Sandri, 2021); individual or group written reflection in entrepreneurship for Computer Engineering (Burden and Sprei, 2021) and in Business (Deer and Zarestky, 2017; Dziubaniuk and Nyholm, 2021); group reports on fieldwork in Built Environment (Holdsworth and Sandri, 2021); across disciplines, a letter to future generations (Tolppanen, Kang and Riuttanen, 2022). Two broad categories are apparent here: assessments which

require students to reflect on their consumer behaviour, and those which focus them on systemic factors. These are often used in combination where they are perceived to help students make a personal connection with systemic knowledge.

Written assignments were not discussed in as much detail as some of the emerging or experimental assessment methods and may be somewhat taken for granted. This was true even when they required groups to engage in the complex and demanding task of collaborating on a single piece of work. This leaves questions about the division of labour within the collaborative writing.

Examinations

Examinations happen in controlled conditions under time constraints. They are not generally considered useful for ESD and accordingly are not very present in this literature. Nevertheless, they are prevalent in universities, partly because they scale to increasing student numbers where there is scant assessor resource. This means that sustainability assessors sometimes need to work with them. Blodgett and Feld (2023) describe how they designed a single exam question to assess the integration of knowledge from an interdisciplinary course that had been team-taught to students from single and combined disciplines. In half of the 13 environmental courses Mintz and Tal (2018) analysed for embedded sustainability content, a final exam was the sole assessment. However, thisarticle did not seek to connect assessment methods with learning outcomes, so it is not possible to comment on their effectiveness. The review by Cebrián Bernat, Segalàs Coral and Hernández Gómez (2019) identified one instance of assessing systems thinking using a short answer exam and a group dialogue exam. This group dialogue exam had been the outcome of class reflection through which students and academics had realised that a standard exam did not “honor the pedagogical philosophy of the class”.

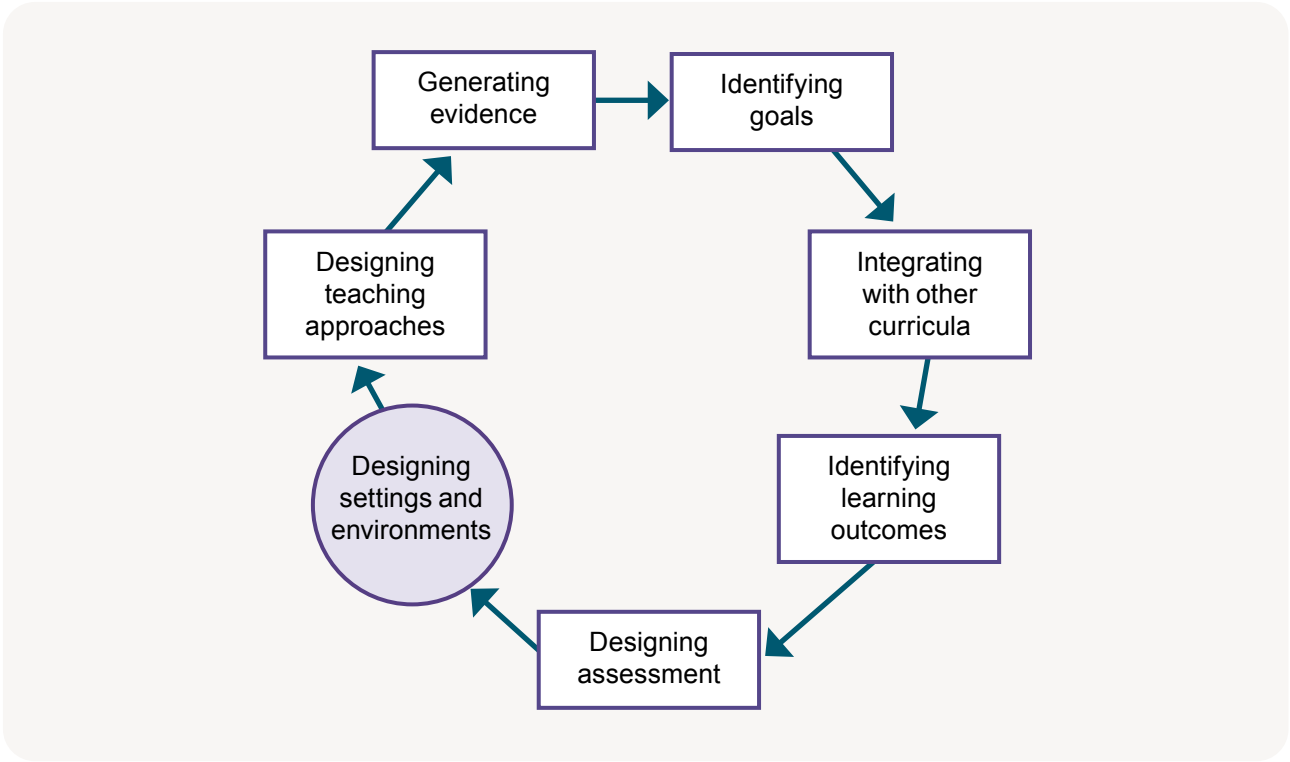
More assessment approaches

The following approaches were mentioned in publications we reviewed but not elaborated.

Self- and peer-assessment depends on a grounding in sustainability knowledge and a thorough induction to criteria. Attempting to integrate sustainability knowledge into Engineering students’ thesis proposals and project development, Sanchez-Carracedo and colleagues (2020) found that their ability to self-assess their projects with a rubric would depend on their sustainability knowledge. Mercer and colleagues (2017) also found that without explicit guidance, peer review of game designs neglected important questions about the intended audience. This is in line with existing insights about criteria and rubrics – they are helpful if students have internalised the meanings of criterion reference statements. Self-assessment poses related challenges. Responding to the over-reliance on self-reporting in ESD assessment, there have been calls to restrict the use of self-assessment rubrics to metacognitive tools for students and stop using them as objective measures of learning (Birdman, Wiek and Lang, 2022).

Capstone courses exist to stimulate students to integrate learning from different disciplines that may not otherwise become truly interdisciplinary (Abbonizio and Ho, 2020; Schweizer, Di Giulio and Burkhardt-Holm, 2019). A rubric to monitor and self-monitor the sustainability learning outcomes of final year Engineering students developed by (Abd-Elwahed and Al-Bahi, 2021) has been successfully used on a capstone course, where it revealed a number of obstacles to sustainability learning outcomes which could be fed back into curriculum design.

Designing settings and environments



This section discusses the environments, encounters and resources which form the context for the teaching approaches. The settings most associated with ESD are interdisciplinarity, transdisciplinarity and external partnerships. We define interdisciplinarity as the integration of different disciplinary organising principles, theories, methods or techniques, through collaboration or adoption, in ways which bridge between disciplines and may in some cases reconfigure them (Klein, 2017). We define transdisciplinarity as oriented to mutual learning between academia and wider society for the public good, using facilitated processes to define real-world problems, jointly with stakeholders where possible, and generating well-contextualised, feasible responses, in some cases working directly with the stakeholders to enact solutions (Scholz, 2020).

There is consensus that sustainability learning outcomes are most likely to be achieved through approaches which mobilise interdisciplinary groups of students to collaboratively solve problems in the real world (or as close to real world as possible), in ways that actively stimulate them to integrate

their diverse perspectives. Ideally this involves collaboration with external partners or stakeholders, which is also considered one of the most reliable ways to increase students' commitment to taking action. It is hard work establishing and facilitating these kinds of settings. Teaching teams in inter- or transdisciplinary courses need to develop themselves as facilitators of interdisciplinary learning, including the frequently encountered bottlenecks of students' agreeing a problem definition, deciding what to do about it and coordinating the work. Some educators may not be resourced to do this. Others may doubt that the work is compatible with their own disciplinary missions, identities and commitments.

Where capacity is not available to set up and nurture external partnerships, the publications we reviewed indicate that educators can deploy vivid real-world examples, case studies and games. Where timetabling or other constraints prevent students from different disciplines coming together, interdisciplinary teaching teams can bring students contrasting perspectives integrate. Where disciplinary specialists are not inclined or not resourced to become facilitators of complex interdisciplinary processes, there can be a separation of roles. Different disciplinary specialists can bring knowledge and methods relevant to a given wicked sustainability problem, while interdisciplinary facilitators can bring students structure for integrating these.

It is important to eliminate any sense that sustainability teaching is a diversion or a personal corrective or it is more likely to meet with resistance or apathy on the part of students. Integrating sustainability closely with an aspect that they recognise as relevant (entrepreneurship in Computer Engineering or audits in Accounting, for example) can dispel the scepticism.

We expand on these themes below.

Interdisciplinarity

Interdisciplinarity (defined in the introduction to this section) is a necessary response to 'wicked' problems that do not respect subject boundaries, involve multiple stakeholders with different perspectives, and require the integration of theory and practice. The literature we reviewed brings insights about integrating knowledge from strong monodisciplinary cultures while respecting their identities, and about bottlenecks which tend to affect inter- and transdisciplinary teams.

Mokski et al (2022) observe that humanities disciplines are underrepresented in ESD and call for the inclusion of humanities ways of working. In this vein, (Blodgett and Feld, 2023) were able to draw some speculative conclusions about learning from an interdisciplinary module co-designed and co-taught by two lecturers in History and Sustainable Food Systems science (Babson College, Massachusetts, USA) to two classes of the two separate disciplines and a third class which combined students from both disciplines. This module aimed to integrate historical, societal and environmental issues essential to a food system's sustainability. The artefacts students created in a group task to design a food label indicated that the combined group had more successfully integrated the knowledge than either single discipline group. Intriguingly, individual responses to a separate exam question showed similar levels of integration.

Working with the grain of a compartmentalised monodisciplinary university culture, leaders of the elective university-wide interdisciplinary sustainability course at Universität Hamburg, Germany decided to separate the knowledge-bringing roles from the facilitative roles in their teaching team (Braßler and Sprenger, 2021). One priority was to protect their educators from overload by organising for expert lecturers external to the core teaching team to teach the disciplinary knowledge. The core teaching team focused instead on developing themselves to support interdisciplinary student groups with problem formulation and projects, including interdisciplinary communication and conflict resolution. Before participating, students had self-reported high sustainability attitudes and moderate sustainability knowledge and behaviour intentions. After this course, self-reported sustainability knowledge behaviour intentions increased across all three pillars (attitudes did not change but had been high at baseline).

Another approach to interdisciplinarity is the redesign of a cross-university sustainability course at the University of Basel, Switzerland after consulting with students and teaching staff (Schweizer, Di Giulio and Burkhardt-Holm, 2019). The heterogeneity of the disciplines involved brought little consensus about the curriculum, so the decision was made for disciplinary experts to interactively lecture separate units on Natural Science, Social Science and Economics. However, since students had previously failed to draw connections between these, the following integrative measures were put in place. A common thematic focus was established by the lecturers and referred to as a point of reference between them, prompting a re-orientation of their respective units. The new programme initiated with a kick-off event stimulating exchange between the lecturers, and concluded with an integrative unit during which students undertook teamwork to integrate the disciplinary knowledge. The evaluation was positive, but the important integrative unit was hampered by the struggle to find a suitable lecturer with interdisciplinary knowledge of the common focus and of interdisciplinary teamwork, who was also available to liaise closely with the other lecturers. We revisit this kind of difficulty in the section ‘Difficulties with interdisciplinarity and transdisciplinarity’ and return to it along with others after discussing transdisiplinarity work with external partners.

To summarise, interdisciplinarity brings multiple perspectives and approaches necessary to tackling sustainability problems. It can also bring disconnected heterogeneity which needs to be anticipated and managed through carefully designed integration.

Transdisciplinary work with external partners

Transdisciplinarity (defined in the introduction to this section) is oriented to mutual learning between academia and wider society for the public good. It uses facilitated processes to define real-world problems, ideally jointly with stakeholders, and generate well-contextualised, feasible solutions, in some cases working directly with the stakeholders to enact those solutions (Scholz, 2020). Transdisciplinarity is born of the recognition that how society responds to sustainability problems often has social foundations rather than technical foundations, “involving social action, institutions, organisations, relationships, culture, motivation, values, meaning, norms, and other social processes” (Serpa and Sá, 2019). External partners, whether in industry, community, government or business, are identified as a source of authentic, appropriately complex real-world settings for practice and

application, empowered citizenship, and social responsibility (Aránguiz et al, 2020; Brandt et al, 2019; Burns and Schneider, 2019; Cicmil, Gough and Hills, 2017; Marouli, 2021; Martínez-Campillo, Sierra-Fernández and Fernández-Santos, 2019; Warwick, Wyness and Conway, 2017). Real-world experiences bring collaborations associated with competency development and are one of the most reliable ways to strengthen commitment to sustainability (Birdman, Barth and Lang, 2022; Martínez Casanovas, Ruíz-Munzón and Buil-Fabregá, 2022).

External partners may be transnational, bringing intercultural interactions and an opportunity to develop normative and collaborative competencies (Li et al, 2018). Challenges for students in these settings include language barriers and cultural difference complicating communication and exacerbating conflicts within teams, and (not exclusive to transnational work) difference in the credit structures of the courses involved leading to uneven effort teamwork (McPherson et al, 2016). In a literature review on transnational collaboration Caniglia and colleagues (2017) identified three overarching strategies for their success: organisational flexibility; structured but flexible forms of communication; and pilot tests and trials.

As we discuss in the section 'Designing teaching approaches', real-world experiences are some of the most potent learning experiences for sustainability. However, they require settings that are resource-intensive to arrange and maintain. If there is no capacity for this, then designing activities through which students can engage deeply with case studies and real-world examples can stimulate them to transfer disciplinary knowledge to societal contexts. For example, Zidny, Laraswati and Eilks (2021) observed Chemistry students used more socio-economic and ethical argumentation after a structured teaching session comparing marginalised and dominant approaches to pest control. Role play can approach real-world experiences. Gordon and Thomas (2018) set up theirs as a TV panel discussion. They grouped students into threes and pairs to fit the time available for short presentations and panel questions, and allocated roles representing particular interests, including coalitions. Subsequently, analysis of students' assessed written reflections found evidence that the roleplay had promoted systems thinking, future thinking, strategic competence, collaborative and interpersonal competence, and normative competence.

Games are another setting which approach the real world. A proportion of Business students playing a simulation game said that it would change the way they did business (Gatti, Ulrich and Seele, 2019). Games are discussed below in the section on 'More settings and environments'.

Difficulties with interdisciplinarity and transdisciplinarity

Difficulties arising from interdisciplinarity and transdisciplinarity are prominent in this literature. We summarise them here before discussing how the publications reviewed suggest addressing them.

One difficulty is frustration with the inherent complexity. Student teachers in education settings face extra layers of complexity as they master knowledge and ESD pedagogies to teach in turn (Ødegaard et al, 2021). Another potential difficulty is persuading students of the relevance of other disciplinary knowledge. While Mokski and colleagues (2022) celebrate the relevance of humanities approaches to ESD, Marcone's initiative in Science (2022) met with resistance from a group of students they judged

unlikely to change their minds about the relevance of social issues to their studies. This particular approach to interdisciplinarity involved incorporating ideas from different disciplines rather than working directly with peers studying different disciplines, which may have been more persuasive. That said, students from STEM disciplines may be at a disadvantage in integrating their scientific analytical and objective approaches with value-driven sustainability discussions (Abbonizio and Ho, 2020; Ceulemans and Severijns, 2019), so interdisciplinary group work needs active facilitation for equity. Moreover, encountering different paradigms, such as the holistic alternative to human/nature dualism described by Druker-Ibáñez and Cáceres-Jensen (2022), can be confronting (Sandri and Holdsworth, 2022; Sivapalan, Clifford and Speight, 2016). Time pressures were generally present, and interfered with the kinds of question-sharing required to reach consensus on the nature of the problem and what should be done about it (Tamura et al, 2018). These challenges may be particularly acute for younger or less experienced students (Ødegaard et al, 2021).

When working with external partners (Oxenswärdh and Persson-Fischier, 2020) identified conflict while negotiating different approaches, unreliability around routines, and struggles with mutual understanding and reaching consensus. Even when the partnership is consultant-client in nature, there is a need for reciprocity (empowerment, mutual shaping, openness) which may not happen on its own (Horn et al, 2022). External partners are diverse in sector and culture, which underlines the need for students to be given structured methods for eliciting the key aspects of their problems. As authentic settings, external partner organisations can also be very constraining. Students starting a collaboration full of enthusiasm and hoping to solve problems for their partner may soon find that organisations can be inert or resistant to outside influence (Burns and Schneider, 2019; Felgendreher and Löfgren, 2018; Holdsworth et al, 2020). Expectations of both students and partners need to be addressed early to avoid disaffection that could cause the relationship between institution and partner to lose trust and break down (Hilger and Keil, 2022).

The complexity external partnerships

At the University of Wuppertal, Germany, Hilger and Keil (2022) studied the experiences of external partners and student teachers in education undertaking a core transdisciplinary project. Interviews with students and partners shed light on the nature of collaborating with partners who were short of time and resources. The study found that problem definition – agreeing on collaboration that meets the needs of both partners, the bottleneck identified by (Tijsma et al, 2023) above – could lead to very different levels of complexity and effort between projects.

They also identified different kinds of transdisciplinarity. In the **'pick-up model'** students worked on a real-world problem but were not in a collaboration with the partner. With **'partners as access-sponsors',** the partners were gatekeepers who could sometimes demand high-quality work which students, being inexperienced, could not guarantee. Where 'students functioned as a link', they provided the partner with information from other sources. There was also **'collaboration along the entire process**' in roughly a quarter of the projects.

The interviews revealed that not all partners were ready to engage with the findings or outputs from students' work. This study generated widely applicable recommendations for productive collaborations between students and external partners, which can be found in the article's Table 1.

Discussing the place of indigenous and local knowledge (ILK) in ESD partnerships, Druker-Ibáñez and Cáceres-Jensen (2022) offer another example of the challenge of integration. They observe two tendencies in approaching ILK from a dominant western viewpoint: one is to explore distinctiveness and the other, synergies. They caution about the synergistic tendency, since the goal of integration is not to dilute ILK into dominant western categories, but to create dialogue between ILK and scientific knowledge. They point out that ILK is not necessarily common between different peoples, though they tend to share a holistic worldview of co-evolving with nature, solidarity with nature and observant connections with territory beyond its use value. Maintaining a distinctive focus is also important to the intergenerational sustainability of ILK itself.

Overcoming the difficulties

In their review of 11 programmes combining inter- and transdisciplinary learning, Horn and colleagues (2022) identify co-creation as essential, and set out to address the absence of concrete strategies to facilitate interdisciplinary knowledge integration. They describe the phases through which students and external partners can be involved in co-creation for interdisciplinarity:

+ co-design – joint framing, formulating researchable questions, and negotiating agreements
+ co-production – integration of scientific knowledge in ways that are societally relevant
+ co-dissemination – open communication and discussion about findings, generating new researchable questions).

They note a tendency for ESD to over-focus on the middle co-production process and call for a rebalancing towards the early co-design stage of joint framing and research definition, and the final co-dissemination stage. There are possibilities for reducing complexity in the framing stage by working on problems already formulated by the partners or developing the work of predecessor groups (Hilger and Keil, 2022; Oxenswärdh and Persson-Fischier, 2020). However, some educators may decide that students should experience the complexity of framing. Gulikers and Oonk (2019) emphasise that students are only likely to take up opportunities for co-creation with external partners if it is explicitly addressed, stimulated and assessed. They provide a rubric to make this more explicit (see the section 'Assessing interactions between students and external partners'). Similarly, Holdsworth and Sandri (2021) advise giving students 'points of entry' into these kinds of complex processes rather than leaving them open, and offering plenty of on-demand support from approachable educators.

Effective group work requires curriculum designers to persuade students of the positive features of difference (Oxenswärdh and Persson-Fischier, 2020; Sanchez et al, 2019) and even conflict (Yeung et al, 2017). Believing that group work is worthwhile is an important part of what sustains students through the emotional and cognitive struggle of navigating disagreement or incomprehension, and examining one's own tacit assumptions (Armstrong et al, 2016; Bryant et al, 2021; Park, Park and Smith, 2021). It is important that students value participatory methods and are confident that they will learn and achieve more that way than they could individually (Ostuzzi and Hoveskog, 2020). This takes purposeful framing, facilitation and monitoring on the part of educators.

Supporting heterogeneous groups to work with external partners

'Projects in multidisciplinary teams' is a course developed as part of the international Master's in Sustainable Destination Development at Uppsala University, Sweden (Oxenswärdh and Persson-Fischier, 2020). Teams of students generate sustainable solutions for problems provided by local businesses, community organisations and authorities on the heavily touristed island of Gotland.

To support interdisciplinarity, the course leaders made some influential design decisions. They collaborated with the external partners to ensure that the problems could not be solved individually but required teamwork. Accordingly, they allocated students to groups based on difference – country, culture and specialist track within the degree – and instructed them to make use of their heterogeneity.

Students were given a substantial two-day induction to using design thinking as a method. Each group selected a locally generated sustainability problem including training for bed and breakfast owners, an accessible tour for disabled visitors, and more business-oriented problems. Each group had a dedicated educator.

Most external partners were satisfied with the students' solutions, valued the new perspectives, and took valuable learning from the experience, though some misunderstandings and ambiguities were not resolved in time. Most students interviewed for the evaluation found the course rewarding and intended to use the design thinking method in future, though they found the iterative process challenging at first and needed the support of their educator. They greatly appreciated learning from their fellow group members but also found that groups needed plenty of time, structure and support to come up with good solutions.

The authors conclude that facilitating groups doing this kind of work depends on holding four counterpoints in balance:

+ balancing freedom and structure entails giving focus without stifling creativity
+ balancing heterogeneity and homogeneity requires enough difference to bring high-quality decision-making and avoid groupthink, but not so much that students cannot reach consensus within the constraints of the project
+ balancing collective and individual responsibility requires each member to be mutually dependent and critically engage with the task instructions
+ balancing group learning and individual learning requires individuals to commit to bringing high quality knowledge to group processes.

On working with external partners, Horn and colleagues (2022) offer further ways of managing complexity. Curricula that limit the disciplines to be integrated or the questions to be addressed tend to be more predictable and therefore easier to implement than those which are strongly student-led, where students' interests may not intersect with those of the partners. Matching students and partners according to interest is important because, as Konrad, Wiek and Barth (2021) note, benefits of these partnerships depend on both partners and the teaching team being willing to 'go the extra mile'. Burden and Sprei (2021) found that this reciprocity is strengthened if the organisations also have their own goal to involve external partners in turn. They also recommend identifying intermediaries in the partner organisations, points of contact who can connect students with appropriate people and resources within that organisation. One way to show appreciation to the partners is to offer them a process for following up good ideas. Beaudoin and Brundiers (2017) have produced a framework for ESD programmes with external collaborations.

Designing a transdisciplinary co-created service learning programme

Working in interdisciplinary groups on real-world problems with external partners demands particular skills and approaches. Students need to arrive at well-defined concrete projects that are feasible to carry out while also integrating the diverse viewpoints needed to do justice to complex sustainability problems. The Community Service Learning (CSL) programme piloted with Master's students at Vrije Universiteit Amsterdam is distinguished by dedicated support in these areas (Tijsma et al, 2023). The programme is composed of two consecutive community service learning courses. Interdisciplinary groups of Master's students undertake a project initially identified by a community partner, and subsequently co-designed, co-produced and co-disseminated through structured approaches.

The curriculum has been carefully designed to avoid the breadth-versus-depth tensions that often interfere with interdisciplinary learning. Since degree-specific and interdisciplinary learning reinforce each other, the courses have managed to some extent to avoid threatening academic departmental missions and identities. This meant that they have been accepted into some Master's degrees in the university for academic credit.

The format is flipped, with theoretical knowledge through self-paced learning and interdisciplinary activities within timetabled sessions. There is formal support for students to integrate their own degree learning with other disciplines, and this is sustained for the duration of the programme. Drawing on their specialised knowledge of inter- and transdisciplinarity, the programme leaders give students an early education in approaches to effective work in diverse teams. Structured activities at optimal phases of the project bring students techniques to arrive at consensus on problem definition, research methods for liaison with community partners and approaches to scientific communication at public events. For the duration of their external project each group is supported by a dedicated tutor.

Students reported that they felt equipped and motivated to continue with inter- and transdisciplinarity beyond the programme. Moreover, the public events attracted high engagement from students, community partner organisations and academics teaching on students' respective Master's degrees and were regarded as valuable networking opportunities. One challenge, considered inherent to interdisciplinary work, is the research definition phase which often causes difficulties for students and partners. This, along with the necessary small group support, and the need for liaison with Master's supervisors, degree programme leaders and community partners, means that there are considerable resource implications for programme leaders.Support from the university leadership would be needed to scale up.

In their efforts to promote relevance, Burden and Sprei (2021) persuaded more Computer Engineering students of the value of sustainability by incorporating it into transdisciplinary teaching about career-focused entrepreneurship, an angle which most students found more motivating than sustainability alone. Entrepreneurship opportunities were also developed by Martínez-Campillo, Sierra-Fernández and Fernández-Santos (2019), who observed that their Business Administration students' grades in a sustainability assessment improved after collaborating in teams with rural town councils to support local entrepreneurs. This is an example of the alignment mentioned in the section on 'Integrating with other curricula' above.

These examples show how teaching teams have differently addressed the challenges of interdisciplinarity and transdisciplinarity and how, if framed and managed well by approachable, appropriately resourced educators, these challenges can be welcomed by students as authentic to the sustainability problems they face, and also to the world of work after university (Abbonizio and Ho, 2020). Like all curriculum development, designing for interdisciplinarity is the product of interdependent decisions and should be thought of as an iterative co-creative process. This work underlines earlier points about educators needing to be good at interdisciplinary facilitation (Ødegaard et al, 2021) and enabled to offer active, contingent support in a scaffolded learning process (Holdsworth and Sandri, 2021). Clearly inter- and transdisciplinarity require plenty of structure and plenty of time (Oxenswärdh and Persson-Fischier, 2020).

More settings and environments

Games and simulations designed to promote ESD-related outcomes can create realistic settings with some of the characteristics of fieldwork or work with external partner organisations. A review by Stanitsas, Kirytopoulos and Vareilles (2019) found that the largest proportion (25 games, 32%) was giving players a holistic sustainability education including all three pillars, while the next largest addressed the environmental dimension alone. A game about keeping global heating under two degrees helped students understand the complexities of climate change and the importance of collaborating for the common good within a wider competitive system (Carreira et al, 2017). A game about waste management brought self-reported pro-environmental changes in attitude, knowledge and intentions, though when compared to equivalent guided inquiry learning, the only significant change was in attitude (Yeung et al, 2017). The authors reasoned that this may be because in the game they played the role of a normal civilian, prompting feelings of remorse and regret about some of their consumer decisions (see also 'Dilemmas, cases, vignettes and scenarios'). Over half the Business students playing a sustainability simulation game said that the interaction had engaged them both cognitively and affectively and had changed their approach to conducting business (Gatti, Ulrich and Seele, 2019). Education students out walking locally used a mobile app with a game mode including a team element. The app introduced them to plant species, historical references and other features of sustainability interest and the students noted interdisciplinary learning (Pombo, 2022). In their review of escape rooms for teaching climate change, Ouariachi and Wim (2020) found they could prompt players to connect causes and consequences of climate change, so activating systems thinking and future thinking competencies, as well as critical thinking and collaborative / interpersonal

competencies, which could be deepened by allowing time for debriefing and reflection. In their bibliometric review on simulations and serious games for ESD, Hallinger and colleagues (2020) noted that less than 15% of this literature has been authored by scholars from Asia, Latin America and Africa and while some learning outcomes may transfer, others are likely to require re-contextualisation. They call for more culturally relevant serious games. One emerging approach here may be for students to create such games, as Cravero et al's (2021) students did. These students (almost all male and on a selective programme), reported improved teamwork abilities and improved knowledge, despite being forced online by the Covid-19 pandemic. The authors make a strong case for the potential of creating games to help students transfer knowledge into new contexts.

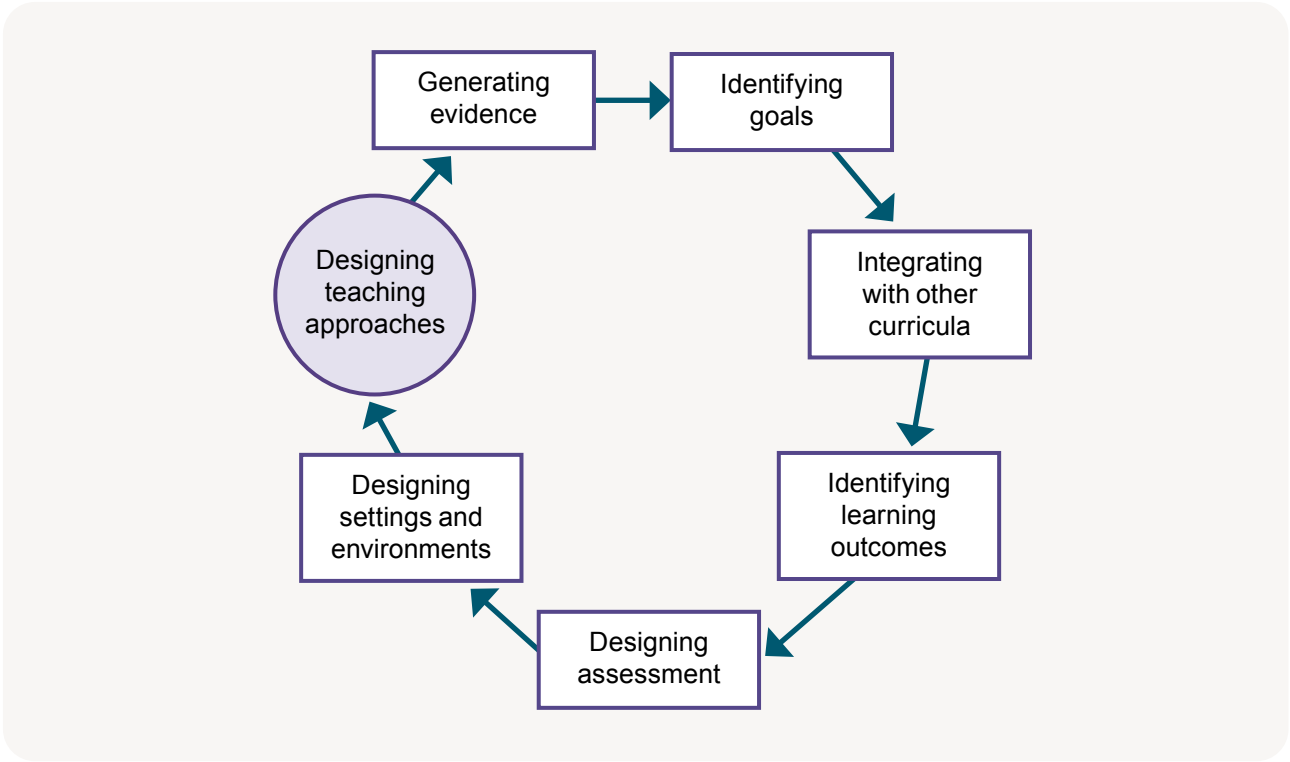
The potential of **digitally networked settings** for surmounting distance is well understood but there is little specific about them in the publications we reviewed. One ambitious example reported over time is the three-day course Frontiers of Sustainability Science jointly offered by an interdisciplinary team from a consortium of five Japanese universities to their students simultaneously, online (Tamura et al, 2018). Initially a heavily lecture-based course, it evolved from interdisciplinary co-teaching towards interdisciplinary learning, first by making space for students to ask questions, then by introducing group discussion, and finally a policy brief task. Despite heroic wrangling with the six-way networked technology, the authors note that the environment was primarily a real-time remote lecture system and less of an enabling space for encounters. This case is summarised in the section on 'Teaching knowledge'. A report about learning in a Finnish government-funded pilot open online course 'Leadership for Sustainability Change' (five ECTS credits) was not specific about teaching approaches beyond a reference to illustrative case studies (Salovaara, Pietikainen and Cantell, 2021)

Fieldwork and site visits are often central to undergraduate science and sustainability education. Compared with physical site visits, drones have been reported as offering equivalent but distinct learning and experiences, each having its advantages and disadvantages. With students of primary education, Palaigeorgiou, Malandrakis and Tsolopani (2017) describe how drones afford a range of perspectives on urban environments but also that, despite close communication with the operator, there are difficulties directing attention. Drones give a purely visual experience lacking other sensual elements. Nevertheless, there were signs that students taking the drone field trip felt more positive about the experience than their on-site counterparts; the authors did not attribute this to novelty effect. For further discussion of fieldwork and site visits, see the section 'Teaching knowledge'.

Local work can feel closer to students' reality, more familiar and more meaningful. This becomes particularly important when local forms of knowledge are not the globally dominant ones. Demssie and colleagues (2020) describe how failure to incorporate local knowledge in the Ethiopian education system has resulted in an education-reality gap, since the dominant European approach to ESD has neglected the collectivist worldview widespread in Ethiopia. Local connections allow students to develop a more observant relationship with the environment, which relates to them feeling involved as "protagonists" (Claro and Esteves, 2021), "citizens in society" (Earl et al, 2018), and hugely motivated (Bryant et al, 2021; Oxenswärdh and Persson-Fischier, 2020). Local context offers great potential for transforming beliefs and behaviours (Hallinger et al, 2020).

We reviewed one article on the **physical environment** that compared a traditional front-facing teaching space to a new space reconfigured for small group interactions (Galan-Casado et al, 2020). Although the hypothesis was that students would rate the new space more highly for a series of variables associated with ESD learning such as paying attention, awakened curiosity and analysing different viewpoints, the survey data revealed significant difference only for visual appeal and participation. In contrast, see the section on 'The pivotal role of educators'.

Designing teaching approaches



We use the term 'teaching approaches' here to incorporate both teaching practices and pedagogical theories about how those practices bring about learning. We also stretch it to encompass the learning activities educators design for students. The publications we reviewed tell us that research connecting pedagogies and teaching approaches with competency development is at an early stage (Lozano et al, 2022; Shephard, Rieckmann and Barth, 2019). Other literature reviewers have concluded that it does not currently provide coherent insights into what should be learned and how, since it is often reports single cases, under-theorised concepts, and descriptive approaches to evaluation (Acosta Castellanos and Queiruga-Dios, 2021; Probst, 2022). Teacher educators caution against seeking silver bullets (Evans and Ferreira, 2020),

> "The literature in support of sustainability pedagogies assumes that there is a particular type of pedagogy that is most effective for achieving third-order, epistemic or transformational learning. Our study findings do not support this supposition."

However, engaging with this plentiful literature does suggest some promising approaches for educators. Fortunately, the teaching approaches most associated with sustainability competencies are already mainstream in university teaching, such as problem- or project-based learning in groups, real-world cases, guided site visits, and work with external partners on their sustainability problems. This means that they are promising for integrating disciplinary and sustainability learning. Sufficient time is an important factor in realising their potential.

To discuss teaching approaches, this section is organised according to the knowledge, values and competencies that we introduced in the section ‘Identifying learning outcomes’.

Teaching knowledge

In professional education such as architecture and education, theoretical or scientific knowledge is closely linked with practice (Malandrakis, 2022; Martin, Serrano-Estrada and Esteve-Faubel, 2021) while in purer disciplines students may be used to thinking of it as the main outcome. Lectures are not on their own associated with deep, enduring learning, but they remain prevalent and in demand in higher education, and often preferred by students to more effortful activities associated with learning. In essence, lectures are an expert demonstrating how to organise and communicate a complex body of knowledge. As such they are most associated with modelling systems thinking and critical thinking (Lozano et al, 2019) but not developing the more practice- or values-oriented competencies. As large group teaching sessions, lectures are perceived to be most effective when they are interactive and varied. This can be achieved through invited expert speakers (Braßler and Sprenger, 2021) and discussions among interdisciplinary teaching teams (Schweizer, Di Giulio and Burkhardt-Holm, 2019; Tamura et al, 2018). Other creative ways to communicate knowledge include embodied and visual methods which enliven perspectives and analysis, such as storytelling in person (Druker-Ibáñez and Cáceres-Jensen, 2022; Merritt, Hale and Archambault, 2019) or through digital media, though students may value this less (Malandrakis, 2022).

Evolution of a sustainability course

A separate, dedicated sustainability course can bring opportunities for external collaboration. In Japan, an interdisciplinary consortium of sustainability experts from five universities established 'Frontier in Sustainability Science', a three-day course for students from different disciplines (Tamura et al, 2018). Its purpose was to develop a common programme of current knowledge and thinking about sustainability which would benefit from the diverse perspectives of the lecturers' individual research fields. Through discussion and assignments, students would turn knowledge from the multidisciplinary series of lectures into complex, interdisciplinary understanding of sustainability problems, as well as developing their strategic and systems thinking competencies. Although the course was compulsory, incorporating it into each institution's degree award algorithm was not possible, so students could earn a certificate instead. The course was taught simultaneously at six sites using networked technology.

At its inception in 2008 the course was heavily lecture-based, reflecting the emphasis on communicating the lecturers' up-to-date research findings. However, as it became clear how students were struggling to integrate the different lecturers' perspectives and wanted to hear from each other, the team initiated several changes in subsequent years. To promote interaction, they extended and structured the time allocated to questions after each lecture to enable students to generate more incisive discussion points within their own university groups. This was followed by a plenary session where each university summarised theirs for the others, a stimulus for interdisciplinary conversation. To support integration, a common theme (climate change) was established, along with introductory and concluding sessions to frame and synthesise the fragmented knowledge. One assignment prompted students to take a position on what they had learned from the different lectures. In another assignment, groups worked on a policy brief for the UN Secretary General, with a ballot for some groups to present their work to the other universities. After 10 years the proportion of lecturing during the three days had fallen markedly.

The evaluation attests to students' appreciation of interdisciplinary activities when synthesising different perspectives, but also the complexity of reaching a shared definition of sustainability problems. The intensive nature of the course is a limiting factor here, providing scarce opportunity to digest and synthesise sustainability knowledge sufficiently to address real-world problems. Students recognised that this course alone would not be sufficient to gain the competencies to solve real-world problems.

Fieldtrips, fieldwork, site visits and place-based education are associated with deepening students' understanding of concepts and increasing social-ecological consciousness (Mammadova, 2021; Marouli and Duroy, 2019; Pombo, 2022; Yoon et al, 2016). Different sites bring different learning depending on, for example, what they teach about human relations and at what level (Mammadova, 2017). The nature of the learning also depends on how students direct their attention; this can be influenced through worksheets (Malandrakis, 2022). As discussed in the section 'Further teaching approaches', Mammadova (2021) notes that the familiarity arising from a site being local seems to deepen students' learning. For fieldtrips to bring deep learning, students need to integrate new knowledge with existing mental models, changing them. This is hard to achieve where the time on site is fleeting. A lack of follow-up studies for ESD raises questions about the link between time pressures and significant, lasting learning, but Pruett and Weigel (2020) reason that spending more time in a site would be associated with stronger conceptual change, beyond simply accruing new knowledge.

Teaching students about equilibrium between the three pillars of sustainability knowledge, Affolderbach (2022) observed environmental orientation dominating her students' project-based learning (PjBL), though she notes this is not unusual in geography. She also noticed that the economic imperative could divert students from pursuing social benefits. She concluded that students may need to be oriented away from "weak" technocentric, sustaining, efficiency innovations and towards what she terms "strong, sufficiency-oriented" interpretations of sustainability. The latter require students to mobilise strategic, future thinking and normative competencies.

Teaching competencies

Key competencies for ESD are set out in Table 2. Research on competency coverage indicates that no single teaching approach can address all competencies, but some address more than others and they can be combined in complementary ways for maximum coverage. This research is nascent, discipline-unspecific and leaves questions about the distinction between coverage and learning or mastery.

In their analysis of 57 completed group projects, Clark and Capps (2020) identified unevenness in how students had addressed ESD competencies. While systems thinking and anticipatory competency were strongly present, normative competency was underrepresented and collaboration required some intervention to avoid it becoming a source of friction. The authors addressed collaboration competency by allocating teams based on individual attributes, prompting students to reflect on these attributes and introducing peer assessment of contribution. They propose addressing normative competency by assigning small group discussion topics during timetabled sessions – for example, a stakeholder analysis, culturally responsive evaluation or stakeholder analysis.

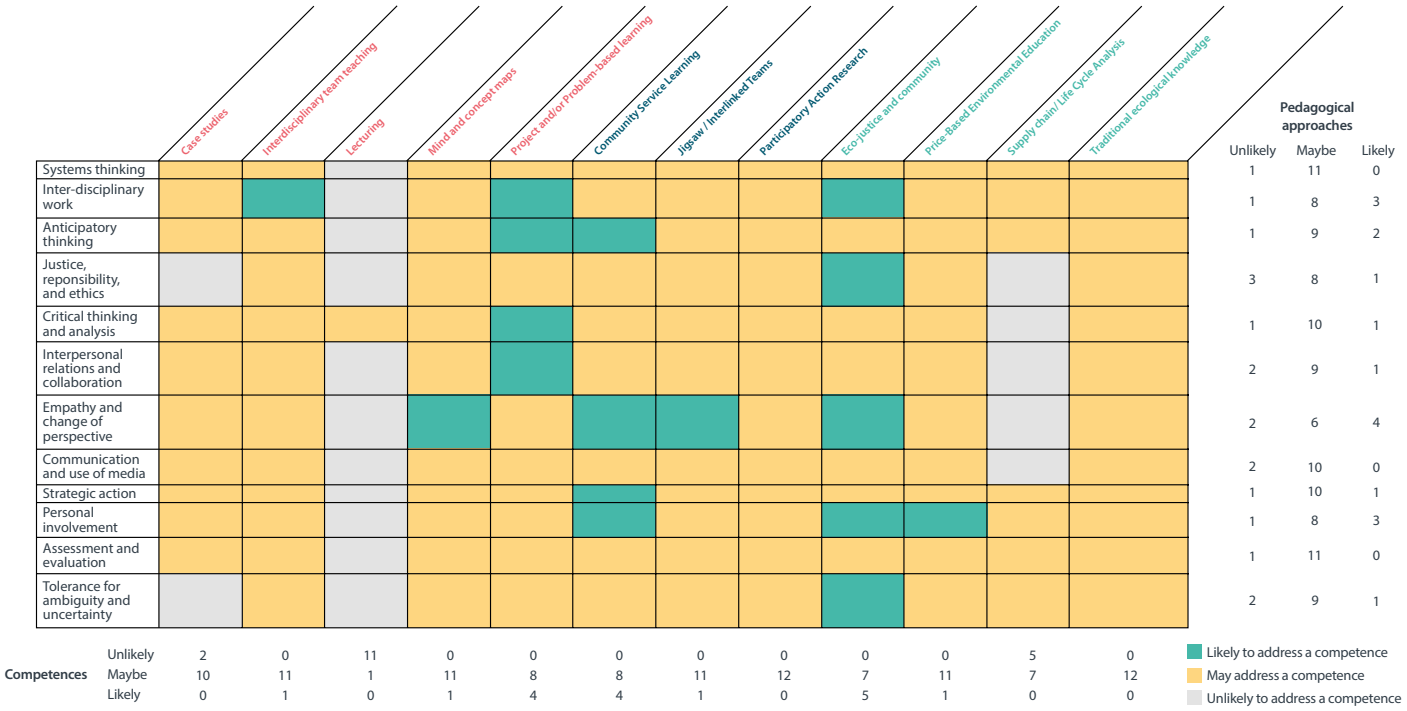
Martínez Casanovas, Ruíz-Munzón and Buil-Fabregá (2022) investigated which active learning approaches students associated with a synthesis of 25 ESD competencies. They surveyed students who had undertaken group discussions and debates, role play, flipped classrooms, case studies, problem-based learning (PBL), real-world experiences through experiential learning, and what they termed "traditional learning". Through cluster analysis they identified four response profiles (categories of students who self-reported mobilising higher or lower numbers of competencies).

Results were mixed, but students in three of the four clusters identified the real-world approach helped them with the competency of decision-making. One novel finding is that students perceived PBL as promoting critical thinking as well as problem-solving but did not perceive case studies as promoting critical thinking. Across the board, they concluded that students perceived real-world experiences, PBL and case studies as best promoting the most competencies.

Lozano and colleagues (2019) used survey responses from 390 mainly university-based European sustainability educators (whose academic fields are not reported) to generate a framework connecting the authors' synthesis of 12 teaching approaches to their synthesis of 12 competencies. These are described in (Lozano et al, 2017) Tables 1 and 2. They include approaches which are already widely used in higher education, such as case studies, interdisciplinary team teaching, lecturing, mind and concept mapping, and project- or problem-based learning. The framework (Figure 8 below) indicates that the teaching approaches that usually or sometimes promote the most competencies are 'Eco-justice and community learning',[1] 'Community service learning' and 'Project-based or problem-based learning' (PBL or PjBL). Each approach is strongest for different competencies, and the authors suggest complementary ways to combine them. Teaching approaches associated with fewer competencies were 'Lecturing' and 'Supply chain / life cycle analysis'.
This framework indicates that, on average, the best coverage of these competencies can be achieved by combining PjBL and/or PBL, service learning and eco-justice and community learning. From this work, it is possible to recommend some teaching approaches on the assumption that they can promote competencies associated with sustainability and disciplinary learning together. However, the approach associated with the most competencies, 'Eco-justice and community learning', seems particular to ESD and likely to be more amenable to integration with some disciplines than others.

1 Lozano et al (2017) describe the 'Eco-justice and community' teaching approach as "involving a deep transformation of mindset on the part of the instructor and students, shifting from mechanistic and industrial metaphors to metaphors rooted in living ecology and biological systems …This philosophical transformation necessarily includes a significant emphasis on the diversity, relationships, autopoiesis (self-creation), and non-linearities that are characteristic of complex adaptive systems. This pedagogy has three main topical foci for critical consideration: (1) Environmental racism and class discrimination; (2) Recovery of the non-commodified aspects of community; and (3) Responsibility to future generations."

Figure 8. Framework connecting a set of pedagogical approaches to a set of ESD competences (Lozano et al, 2019). It shows how different pedagogical approaches can be combined to optimise the spread of competences addressed. The bottom block summarises the potential for a given pedagogical approach to address multiple competences at once. The right-hand block summarises how amenable each competence is to being addressed by approaches from this set. Taken as a whole, the combination of pedagogical approaches most likely to address the most competences is 'Project and/or problem-based learning' and 'Eco-justice and community' approaches, with 'Community service learning' offering to address one further competence.



Building on the work of Lozano and colleagues (2017, 2019), Wang, Sommier and Vasques (2022) grouped the sustainability competencies into two broad categories, namely thinking and action. Through a questionnaire completed by 420 students who had taken a sustainability course in that institution, they sought to establish causal links between students' perceptions of competency coverage and the three pedagogical approaches identified by Lozano and colleagues (universal broadly applicable, community and social justice, and environmental education). Wang and colleagues found that only the universal broadly applicable pedagogies (case studies, interdisciplinary team teaching, lecturing, mind and concept maps, project- and/or problem-based learning) were associated with both action- and thinking-oriented competencies (the other pedagogical approaches were associated with one or the other). This is promising since these established pedagogies are more likely to be present in disciplinary teaching; if so, their presence makes it more straightforward to integrate ESD.

Drawing on the abundant case study literature we reviewed, next we briefly introduce some of the learning activities associated with competencies. Caution is needed here since learning activities need to be designed for specific purposes and contexts and cannot be unconditionally connected with learning outcomes. For more detail, refer to the database accompanying this report.

Improved **systems thinking** has been observed further to PjBL in Sustainability Science (Birdman, Wiek and Lang, 2022) and Accounting (Sales de Aguiar and Paterson, 2018), and further to PBL in Engineering, as long as students are explicitly supported to integrate their knowledge from different disciplines (Ostuzzi and Hoveskog, 2020). Systems thinking is also associated with games that require students to address a multifactorial problem (Carreira et al, 2017), critical inquiry and self-reflection (Dziubaniuk and Nyholm, 2021; Sherman and Burns, 2015). **Integrated problem solving** competency is associated with PBL (Affolderbach, 2022; Martínez Casanovas, Ruíz-Munzón and Buil-Fabregá, 2022). **Collaborative/interpersonal competency** is associated with interaction and exchange among students (Birdman, Redman and Lang, 2021; Konrad, Wiek and Barth, 2021) and with PjBL (Holgaard et al, 2016), one promising example of which is making games (Cravero et al, 2021). Interpersonal competency may be developed informally, for example defending sustainability to family and friends (Birdman, Barth and Lang, 2022). For future thinking, Gardiner and Rieckmann, (2015) analysed students' journals in an elective sustainability course and found some topics, such as values, transport and population model, elicited more future thinking than others. They also found activities such as scenario planning, forecasting and backcasting (envisaging a desired future and identifying what needs to be in place to make the transition to it) helped their students better understand the future. Dziubaniuk and Nyholm (2021) found future thinking arising from students' lectures or reading if they were stimulated to reflect on these. For developing **normative competency** in teacher education, Weinberg and colleagues (2020) emphasise the transformative power of "disorienting dilemmas, which refer to experiences that challenge a learner's thinking and prompt them to question the validity of pre-existing meaning structures"; however, while these students felt empowered to change on a personal level, they rarely came to see themselves as "agents of collective, policy-directed, or collaborative change". Another approach found to promote normative competency (here, in students learning to become sustainability-oriented peer mentors) is the Burns Model, a design process integrating multidisciplinary, thematic content, diverse and critically questioning perspectives, a participatory, experiential process and a place-based context (Sherman and Burns, 2015). The Burns Model, "through an intentional emphasis on integrating multiple and non-dominant perspectives into a course, may help students increase their understanding of socio-ecological equality in a world that is marred by unequal distributions of power and wealth". This fits the description of paradigm-challenging creative learning spaces which are important for normative competency development, among others (Davidson, Prahalad and Harwood, 2020). **Critical thinking** is a competency associated with reflective journaling (Gardiner and Rieckmann, 2015) and with Socratic dialogue in architecture (Martin, Serrano-Estrada and Esteve-Faubel, 2021). It is the only competency Lozano and colleagues (2019) associated with lectures, which may be because students see it modelled by the lecturer. In sustainability science, development of practice competencies (**strategic, collaboration, integrated problem-solving** – sometimes called 'action competencies') is associated with PjBL that has real-world connections and plenty of interaction (Birdman, Barth and

Lang, 2022; Chen and Liu, 2020). Self-awareness is associated with reflection (Konrad, Wiek and Barth, 2021; Serpa and Sá, 2019) and is another competency which can develop through reflective journaling (Gardiner and Rieckmann, 2015; Tolppanen, Kang and Riuttanen, 2022).

Sustainability competencies are not evenly addressed (Algurén, 2021; Lozano et al, 2019; Park, Licon and Sleipness, 2022). Barriers to teaching competencies include absence of explicit instruction, absence of opportunity or stimulus to implement them in curricula, lack of knowledge, unchallenging curricula, and absence of a link between theory and practice (Birdman, Barth and Lang, 2022). Moreover, as we have mentioned, acquiring competencies does not inevitably lead to change. The next section is concerned with teaching the values that support this transformation.

Teaching values

As set out above, sustainability values – attitudes, dispositions, worldviews – are one catalyst through which sustainability knowledge becomes sustainability action. For the kinds of transformation ESD seeks, students need to develop new values. This is far from straightforward. Holdsworth and Sandri (2021) emphasise that sustainability is distinctive in its interdisciplinary, subjective and controversial nature, and its demand for value judgements. However, values are hard if not impossible to teach and may be resisted by students who perceive them as out-of-place in their degree or who, in exercising their critical thinking, reach different conclusions about sustainability (Shephard, 2021).

In interdisciplinary learning, it helps to be aware that these values are recognised differently within and across different disciplines. In the publications we reviewed they take different forms, including a more environmentally responsible mindset in Accounting students (Sales de Aguiar and Paterson, 2018); appreciation and conservation of nature in student teachers (Martín-Ezpeleta, Martínez-Urbano and Echegoyen-Sanz, 2022); a sense of being part of nature and co-evolving with it (Druker-Ibáñez and Cáceres-Jensen, 2022); resilience (Birdman, Barth and Lang, 2022); a sense of being a “critical stakeholder” (Kinoshita et al, 2019). Where values include readiness to act, they take the form of a willingness to undertake sustainability advocacy and persuade others (Cordero, Centeno and Todd, 2020; Singer-Brodowski, 2017) and agency, personal responsibility and locus of control (Merritt, Hale and Archambault, 2019)

Reflecting on knowledge is a powerful catalyst in developing these values, particularly when it is done affectively in the light of individual values and responsibilities. Felgendreher and Löfgren (2018) describe how sustainability teaching that engaged their business students in reflection on their individual responsibilities as consumers, citizens and future decision-makers affected their beliefs about what was socially appropriate, compared to sustainability teaching that focused on information only. This reflective perspective-taking is also at the heart of the pedagogy set out by Sherman and Burns (2015) and is key to sensitising students to different needs. Over half of business students playing a sustainability simulation game fed back that the emotional involvement in the setting along with the interactions had changed their approach to conducting business (Gatti, Ulrich and Seele, 2019). In engineering and sciences there has been an evolution of teaching from scientific-technical knowledge ‘about sustainability’ towards more social contextualisation which requires students to reflect on their role in wider society (Holgaard et al, 2016).

Similarly, Burden and Sprei (2021) discuss how their students found that reflecting on something they initially regarded as a distinctly technical challenge imbued it with new meaning and relevance. There is a compelling case for persuading more sceptical students and colleagues by making reflection central in ESD teaching (Rodríguez Aboytes and Barth, 2020). Although some students may find reflection novel or uncomfortable (Birdman, Redman and Lang, 2021), it is key to learning from the kinds of real-world experiences that are indicated above because people don't learn from experience alone but from reflection on experience (Burden and Sprei, 2021). Reflection can be structured and stimulated at different levels from descriptive to critical, bringing in more alternative perspectives and deepening learning through relating personally to material and questioning the premises that exist in the world and in oneself (Burden and Sprei 2021; Rodríguez Aboytes and Barth, 2020). In the study of experiential sustainability learning by (Birdman, Redman and Lang, 2021) all students found discussing their studies with an outside individual helpful. To summarise, reflection is a crucial part of developing values but is unlikely to occur without dedicated space and structured approaches in curricula.

Further teaching approaches

As well as the synthesis by Lozano et al (2019) in Figure 8, the review by Park, Licon and Sleipness (2022) in planning and design presents teaching approaches according to the ESD approaches they enact (presented in Figure 3). They also present a chart of benefits, but without the context it is impossible to associate the benefits with particular approaches. Context is crucial. The publications we reviewed were mainly case studies in single disciplines. This brought many creative approaches, but limited methods and reporting means that their findings are not generalisable beyond their context, and to attempt to summarise the approaches would yield only a dislocated list.
Instead, we refer readers to the dataset accompanying this report. It can be filtered by academic subject and keyword searches can narrow down to particular subject areas, learning activities and teaching approaches. We recommend reading in full any relevant articles there. The literature reviews in a separate tab of the dataset bring higher level insights.

The pivotal role of educators

In the publications we reviewed, there was often little on the considerations that influence pedagogical decisions about how to teach particular disciplinary or subject knowledge to a particular group of students in a particular context. This professional judgement is sometimes referred to as Pedagogical-Content-Knowledge or Technological-Pedagogical-Content Knowledge (Mishra, 2019; Shulman, 1986) and is often tacit. For example, Martínez Casanovas, Ruíz-Munzón and Buil-Fabregá (2022) found that one group of students perceived the 'traditional' classroom as a favourable approach for interaction and exchange, an unexpected result which suggests that their educator played a distinctive role. Educators are responsible for the integration of competencies, knowledge and values through the activities they facilitate, the atmosphere they create and the contingent decisions they make (Singer-Brodowski, 2017).

Probst (2022) describes current ESD literature as “well-behaved”, unconfrontational and not transformative. If ESD is to transform, educators have a vital role in giving students permission to transgress and sustaining them to do so. Without this encouragement and guidance, students’ work is likely to be constrained by existing norms (Holdsworth et al, 2020; Marouli, 2021) and tend towards “weak” technocentric, efficiency orientations to sustainability. Affolderbach (2022) advocates for promoting the kinds of “strong” sufficiency-oriented interpretations which tend to be disruptive. In circumstances of assessment, students are also likely to need explicit permission to overcome their perceptions about what is socially appropriate (Felgendreher and Löfgren, 2018; Pailman and De Groot, 2021; Winks, 2018).

Learning about wicked problems and existential threats often brings deeply unsettled learning conditions and associated emotions of disorientation, shock, fear and hopelessness (Yeung et al, 2017). Sustainability educators draw on their experience and judgement to create learning conditions which are supportive and at the same time ‘brave’ – intellectually unsafe enough to trigger learning (Rodríguez Aboytes and Barth, 2020; Winks, 2018). They support their students as they struggle to “live with the anxiety of not knowing by fostering characteristics such as openness, flexibility, self-reliance and adaptability” (Davidson, Prahalad and Harwood, 2020). Educators bring “critical hope” (Winks, 2018), which is particularly important for student educators (Tomas, Girgenti and Jackson, 2017) and for the motivation and resolve that enables students to develop future thinking competency (Gardiner and Rieckmann, 2015). Educators also guide students in balancing the three pillars, defining what is in or out of scope for a given piece of work to avoid overwhelm, and helping to tackle the bottlenecks of problem definition.

Educators persuade students that sustainability is relevant to their studies. They may face student resistance due to the perceived irrelevance of the knowledge or the unfamiliar approaches to learning (Burden and Sprei, 2021; Ceulemans and Severijns, 2019; Tolppanen, Kang and Riuttanen, 2022). Where students are compelled to study sustainability, educators can expect a more difficult job (Gatti, Ulrich and Seele, 2019). Educators of sustainability integrated with other disciplines must use their subject and teaching knowledge to enthuse those students about sustainability, “proving its relevance and legitimacy as a subject in a course of study” (Holdsworth and Sandri, 2021).

Educators need to bring about equity where demographic differences influence student outcomes. A review of gender difference in waste management education found that some studies reinforced gender stereotypes, responsibilising and emotionally affecting women (dos Muchangos and Vaughter, 2018). Disciplinary differences and sex differences have been found to have independent roles in student ESD outcomes, so making ESD relevant requires careful curriculum design to avoid attainment gaps (Redman and Redman, 2017; Tolppanen, Kang and Riuttanen, 2022).

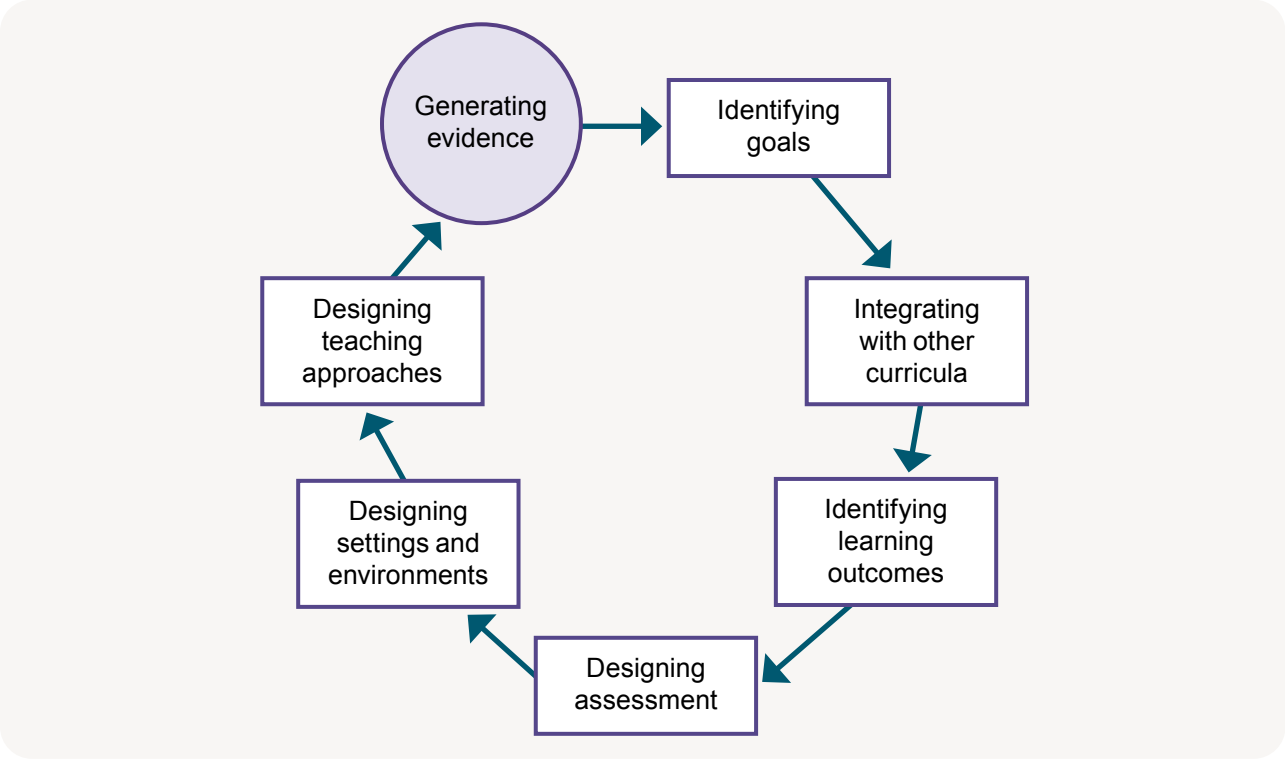
Educators scaffold complexity, framing sustainability based on what their students know and can do, bringing focus to avoid overwhelm and disconnection (Brandt et al, 2021), and helping students to make sense of interdisciplinarity (Mintz and Tal, 2018; Schweizer, Di Giulio and Burkhardt-Holm, 2019). They support their students to develop effective academic practices (Warwick, Wyness and Conway, 2017). Effective learning in group work is key to ESD. Educators must decide whether and how to intervene in group allocation, structure, decision-making processes and division of labour to create conditions of success calibrated to those students' needs, while also enabling them to develop these capabilities themselves (Affolderbach, 2022; Clark and Capps, 2020; Corazza, Cottafava and Torchia, 2022; Hermann, Bossle and Amaral, 2022; Pujol and Tomás, 2020; Schweizer, Di Giulio and Burkhardt-Holm, 2019).

Educators make judgements about the pace of learning. Touring students through sequences of learning activities can hinder competency development unless educators make time for students to reflect and talk with others (Birdman, Redman and Lang, 2021). Well-judged pauses and thinking time are crucial (Warwick, Wyness and Conway, 2017). In experiential learning, it is essential to create time for reflection, since students learn little from experience that is of value to wicked problems unless they reflect (Birdman, Redman and Lang, 2021; Ouariachi and Wim, 2020). Students, particularly early on, are unlikely to have the experience or metacognition to create these opportunities on their own. Educators also set milestones and deadlines, helping students through the bottlenecks of interdisciplinary problem formulation (Hermann, Bossle and Amaral, 2022).

Educators assess learning by designing strategies beyond self-assessment. Designing appropriate and fair transdisciplinary assessment strategies is demanding. Assessing diverse creative artefacts requires judgement and calibration. Assessing group work in ways which elicit effort and collaboration from all members and does not create perverse incentives requires knowledge and experience (Clark and Capps, 2020).

We believe that while educator characteristics are not prominent in the publications reviewed (which explored connections between curriculum elements and learning) they are addressed more thoroughly in the literature on educational development for ESD. We recommend investigating this research.

Generating evidence



The preceding sections have set out the evidence published by ESD educators and researchers since 2015. The abundance of mainly case-based literature offers inspiration to practitioners in particular disciplines. However, they pose challenges for generalisation. Evaluating ESD is clearly difficult, because of the inherent complexity and transformative ambitions of ESD, and because students arrive with their unique prior knowledge, dispositions and experience, which lead them to interact with peers and curricula differently (Birdman, Barth and Lang, 2022; Birdman, Wiek and Lang, 2022; Burden and Sprei, 2021; Foley et al, 2017; Remington-Doucette and Musgrove, 2015; Rodríguez Aboytes and Barth, 2020; Sanchez-Carracedo et al, 2021; Tolppanen, Kang and Riuttanen, 2022). Moreover, chronic under-resource limits the methods available to ESD researchers.

To avoid delays associated with trial and error, ESD requires holistic, valid, well-reported research that sheds light on the pedagogical approaches associated with students and graduates becoming instrumental in contributing to sustainability in their communities and workplaces. Authors of recent literature reviews call for more valid, reliable methods beyond students' self-assessments, and more follow-up over the longer term (Acosta Castellanos and Queiruga-Dios, 2021; Evans and Ferreira, 2020; Probst, 2022; Shephard, Rieckmann and Barth, 2019). Measures need to be developed and validated (Kuehl et al, 2021).

Though not focused on ESD, an overarching recommendation from an evaluation of 30 nationally funded projects on learning gain (Kandiko Howson, 2019) is that multiple measures are needed to capture the complexity and diversity of the kinds of multidimensional learning ESD aims to bring about. We summarise these for ESD in Table 3.

Table 3. Recommendations about sources of evidence for ESD, based on more general research on evaluating learning gain (Kandiko Howson, 2019)

ESD learning	Recommended methods for measuring learning gain	Rationale and conditions
Knowledge	Data about academic performance in assessment; attainment data.	Assessments need to be valid and reliable to ensure that changes in institutional processes are not responsible for changes in student attainment.
Values	Existing and bespoke instruments for self-reporting; observations of educators and external partners.	Self-assessment is subject to social desirability bias and differences in students' ability to reflect. Self-assessment needs to be triangulated with other sources of evidence.
Competencies	Existing and bespoke instruments.	Different measures exist for capturing ways of thinking, practising and knowing. Instruments to measure critical thinking and problem-solving competencies may be more common in education than those for future thinking, strategic or normative competencies.
Across all learning	Develop a conceptual model of how students are expected to learn in a given context	This contextualisation helps with communicating underlying theories or assumptions, and justify the methods adopted for measuring learning. This helps with recruiting students to studies.
	Collect entry and outcome data.	To identify change, it is important to collect baseline data at entry or before an intervention.
	Engage and retain students as participants through aligning with their learning.	Aim to integrate the research with their learning rather than asking them to divert time for a research project.
Longer term outcomes during and after the degree	Multiple points in time	Learning is not linear, so simple one-shot measures may detect learning loss. Qualitative interviews are better at detecting learning gain.
	Follow up studies of outcome measures.	Outcome measures need to be carefully contextualised to avoid becoming targets rather than measures of learning. Longitudinal projects require time and energy to set up, run the project and analyse the data. To avoid attrition, instruments need to be straightforward and not onerous for students to use.

Synthesis of findings

This review set out to identify how ESD has been framed and formalised as learning outcomes, how it is taught and assessed, the student outcomes associated with these practices, and the barriers that exist. We found higher education in transition between articulating the wickedness and complexity of sustainability problems, and beginning to explore how they can be addressed in curricula to bring about social, economic and ecological transformation. In common with other recent reviews of literature, we discovered that research is mainly carried out by the implementing educators, perhaps with support from a central educational development team, in the form of single cases using descriptive methods with small samples. There is consensus that ESD is not yet mature or generalised (Acosta Castellanos and Queiruga-Dios, 2021; Evans and Ferreira, 2020; Probst, 2022; Shephard, Rieckmann and Barth, 2019). However, the abundance of cases reviewed points in some clear directions.

The case for establishing ESD as core, cross-degree and integrated with students' disciplinary learning is compelling (Marouli and Duroy, 2019; Mburayi and Wall, 2018; Weinberg et al, 2020; Weiss, Barth and von Wehrden, 2021; Weiss et al, 2021). The alternative – sustainability content without disciplinary framing – tends to be either unmanageably broad learning about sustainability or limited in scope to personal waste and emissions audits and consumer behaviour change. Extra-curricular sustainability education, because dislocated from disciplinary teaching and accommodating huge variation in prior knowledge among its students, tends towards what Affolderbach (2022) calls shallow 'efficiency' responses, rather than enabling students to pursue critical, transformative measures with wider social impact. It is helpful that competencies and values associated with sustainability are already established as intended learning outcomes for many university courses. This is a good starting point for imbuing them with sustainability content to horizontally integrate ESD within existing core curricula. The publications we reviewed indicate that this is the strongest approach to ESD.

ESD learning outcomes seek to prepare students as agents of transformation to avert a polycrisis of unsustainability. Consequently, while learning outcomes for sustainability are the kinds of knowledge, values and competencies common across higher education (Kandiko Howson, 2019), they are insufficient. The scale and urgency of the crisis imply a further outcome: willingness or readiness to act (Shephard, Rieckmann and Barth, 2019). Knowledge brings sustainability awareness to students, competencies bring them sustainability know-how, values bring sustainability concerns, but it is readiness to act that transforms these into intentions and ultimately, intervention. As agents of transformation, students need this combination of volition, responsibility and tenacity, since they will inevitably face inertia or resistance in their communities and workplaces (Hilger and Keil, 2022; Horn et al, 2022; Oxenswärdh and Persson-Fischier, 2020). Yet the prevailing policy to only formalise outcomes that are going to be assessed for academic credit means that those learning outcomes that are more aspirational and therefore unassessed, including readiness to act, may not be formalised (Shephard, Rieckmann and Barth, 2019). We would expect this to particularly affect modular education systems since these tend toward fragmentation. The role of individual educators is therefore essential here to ensure that these less explicit learning outcomes do not fade but remain alive in all the curricula of the degree programme. The wider institution is also instrumental, since a

whole-organisation approach to sustainability that encompasses all staff and all processes helps to avoid a hidden curriculum through which students pick up disorientating, contradictory messages about what is really important (Braßler and Sprenger, 2021; Mburayi and Wall, 2018; Shephard and Egan, 2018; Disterheft et al, 2015).

Assessing ESD requires students to demonstrate they have achieved their formal learning outcomes. They also need to demonstrate the aspirational ones which are not necessarily written down or assessed for credit. This may be one reason why it was sometimes hard to distinguish the terms ‘assessment’ and ‘evaluation’ from each other in the publications reviewed, leading to what looked like promising approaches to assessment sometimes being presented as evaluation methods. Conversely, where evaluations of sustainability learning were well-developed, there was sometimes little discussion about assessing disciplinary learning outcomes. This hints at possible challenges integrating sustainability and disciplinarity learning. Unless there is a redesign at the module or programme level, it is not always easy to change an existing form of assessment. In the publications reviewed, it was not always easy to tell what students were asked to complete for academic credit, and what was optional or unassessed. It may be that the forms of assessment presented as evaluation approaches existed to detect the unassessed, aspirational learning outcomes, whereas the more established forms (written assignments were prevalent) were assessing the established, formalised ones. There is a need for assessment methods which mobilise learning outcomes assessed for credit while also stimulating students to demonstrate those which are important but cannot or should not be measured (Birdman, Wiek and Lang, 2022; Redman, Wiek and Barth, 2021). There is a need to reduce the reliance on self-reported measures of learning since, although prevalent in evaluating and assessing ESD, they are not robust.

The settings in which students develop and practise their knowledge, values and competencies can be more or less demanding for educators to establish and maintain. Unsurprisingly, the more demanding settings are associated with more deeply and enduringly transformative student outcomes. These are inter- and transdisciplinary settings in which groups of students bring knowledge and methods from different disciplines to their work together on projects addressing real-world problems faced by external partners. However, inter- and transdisciplinary learning requires structure and scaffolding. The most sophisticated approaches give students a parallel education in working together across difference, and include techniques for eliciting information, arriving at a shared problem definition, deciding on action, resolving conflicts, liaising with external partners, and communicating with non-specialist audiences (Hilger and Keil, 2022; Oxenswärdh and Persson-Fischier, 2020; Tijsma et al, 2023). Optimally, scaffolding is tied to the project schedule so that specific guidance is timely, and students can grasp the relevance of each method and technique. It is these processes that bring integration. Without them, student group work is prone to reproduce the problems which entrench sustainability in wider society: problems may not be well-understood; efforts may be uncoordinated or misdirected; and the strongest voices are likely to exert undue influence.

The most carefully scaffolded inter- and transdisciplinary approaches also seem to be well-resourced, though this is sometimes to do with the extra effort the course team is able and willing to contribute, rather than institutional resource, in which case it is unsustainable. However, if resource for the strongest approaches to ESD is not available, teaching approaches that are already widespread can promote sustainability outcomes if they are appropriately oriented and supported.

Research seeking causal links between teaching approaches and sustainability competencies concludes that the best coverage of competencies can be achieved through teaching approaches that are already well-established in higher education (Wang, Sommier and Vasques, 2020; Lozano et al, 2019). The findings of Martínez Casanovas, Ruíz-Munzón and Buil-Fabregá (2022) complement this work. They conclude that students perceived real-world experiences, PBL and case studies as best promoting the most competencies. We found less research about developing values than competencies, but dedicated time, space and support for critical reflection on content, process and premise is crucial to the transformation ESD seeks (Rodríguez Aboytes and Barth, 2020). There are signs that learning activities associated with individual consumer behaviour (for example, waste audits and carbon footprints) may help students recognise the connections between the personal and structural realms. However, while these personal changes may have a very potent effect when aggregated, they are not associated with wider structural transformation which would design out the choice of an unsustainable lifestyle. Lecturing is not associated with transformative learning outcomes but was frequently mentioned in passing as a way to give students the disciplinary and sustainability knowledge that is foundational to developing competencies, values and volition. For timetabled lectures there are ways to improve the learning from large group sessions through interactivity, multimedia and external speakers with first-hand experience of the topics being taught (Holdsworth and Sandri, 2021; Tolppanen, Kang and Riuttanen, 2022). For flipped learning with recorded lectures, the corresponding timetabled sessions are where students are given the opportunity to deeply comprehend the knowledge through practice and application activities.

Educators and their agency play a pivotal role in the ethos and culture of ESD. The inappropriateness of coerced academics successfully teaching sustainability competencies such as critical thinking and self-awareness is a strong theme in the publications we reviewed. Democracy, collegiality, agency, personal engagement and motivation on the part of educators is key, or the quality of the education is likely to degrade (Armstrong et al, 2016; Shephard et al, 2021). Reservations may persist among educators, particularly in hard, pure disciplines, about whether sustainability has a place in their curricula (Clarence-Smith, 2023). Addressing these reservations at the institutional or national level raises some important principles to keep in mind. One is that independent disciplinary identities are an asset to ESD and the basis of a profound and fruitful interdisciplinarity (Pabst, 2023; Tijsma et al, 2023).

Finally, clarity is needed about what ESD in higher education should aim to achieve (Probst, 2022; Shephard, 2021). Yet, with exceptions, this review did not find that higher education has made a consistent or concerted effort to gain the attention and commitment of their academic communities to think this through. Sustainability is often left to compete in the marketplace of ideas, which characterises research-oriented universities in liberal democracies. This marketplace is already crowded with concerns such as entrepreneurship, ethics, employability, equality and diversity, digital capabilities, information literacy, intercultural competency, often arising from national agendas, but prone to become compartmentalised and competitive for curricular attention. It is uncertain that universities are resourced for the kind of contingent, demanding teaching that the complexity of ESD implies. In the UK, for example, student numbers are uncapped, universities compete with each other, education often subsidises research, even in prestigious research-intensive universities, with the tacit approval of the student bodies (Wolf and Jenkins, 2021). Staffing is not always commensurate; see for example HESA data over recent years at Manchester and Bristol, where rises in student numbers have outstripped rises in academic staff numbers, and Sussex where academic staff numbers have decreased). To avoid a hidden curriculum which communicates to students that sustainability is a niche concern that will not be valued or rewarded in the wider world, universities need a whole-institution approach which creates synergies among initiatives in efficient, energy-conserving ways (Weiss, Barth and von Wehrden, 2021).

Recommendations and implications

The following implications and recommendations are duplicated in the executive summary.

For educators

+ **Integrate sustainability into core curricula wherever possible.** This approach is most associated with the transformative goals of ESD because it treats sustainability as part of the discipline rather than adjunct.
+ **Aim to integrate the interdisciplinarity in ways that reinforce students' disciplinary learning.** Designing interdisciplinary group work to build on disciplinary learning helps to reach all students rather than only the willing. It helps to persuade students of the relevance of sustainability where this is not obvious. Most straightforwardly, this could take the form of giving students sustainability problems or cases through which they practice applying new disciplinary skills or concepts. At its most advanced it could take the form of incorporating inter- or transdisciplinary sustainability learning into a disciplinary degree programme.
+ **Prepare to communicate the concepts of sustainability and their inter-relationships to students and colleagues.** This will help to address longstanding problems conceptualising sustainability. Reaching a shared understanding of these in each context will help with consistent, productive engagement. Rubrics describing assessment criteria and levels of achievement are promising starting points for discussion here.
+ **Create space for students to interpret learning outcomes and assessment criteria together.** This is already widely accepted as beneficial, but is particularly important in interdisciplinary or transdisciplinary settings since these often bring contrasting approaches to a single task. This clarification needs to be a collective process to contextualise the learning outcomes and criteria and interpret what is ambiguous.
+ **Consider how to maintain focus on learning outcomes that are aspirational but will not be assessed for academic credit.** These may include competencies and values such as self-awareness and willingness to act for sustainability. Where there is a decision not to assess these, they are unlikely to be formalised as learning outcomes and are prone to be obscured. Bringing them to the fore is particularly important where ESD is embedded into disciplinary learning.
+ **Guide students to integrate knowledge in interdisciplinary settings.** Students generally need support to integrate different disciplinary knowledge, beyond simply accumulating it. A common topic or theme brings valuable focus here. Where courses are team-taught by disciplinary specialists across faculties, coming together for early introductory framing and concluding synthesis sessions can model for students how different disciplines can respond to each other as they address a given problem.

+ **Facilitate students' interdisciplinary and transdisciplinary group and project work.** Students need methods, facilitation and time to navigate common difficulties of problem identification and action planning, and to become effective group members. Specific guidance and methods enable students to comprehend and engage with other perspectives, represent their ideas, reach consensus, and manage the work equitably. Examples include concept maps to visualise perspectives and focus points of difference, causal trees to arrive at a shared problem definition, joint data analysis, and structured approaches to dialogue and communication.
+ **Incorporate teaching approaches and learning activities associated with sustainability competencies.** Teaching approaches that are already widely established in disciplinary curricula are promising in developing the widest range of sustainability competencies. These are project-based or problem-based learning, real-world experiences or cases. Other teaching approaches associated with environmental education and community and social justice are useful in teaching narrower groups of competencies. No single approach addresses all sustainability competencies, but they can be combined in purposeful ways.
+ **Create space and structure in the curriculum for critical reflection.** This is key to developing values which mobilise sustainability knowledge and competency into action. Reflection – a process of analysing content, process and premises in the light of alternative perspectives – is key to the development of values and subsequent intention to act. Students need guidance to move from descriptive to critical levels of reflection through which they come to question underlying premises in the world and in themselves.
+ **Anticipate demographic and disciplinary differences about what is perceived as appropriate when tackling sustainability problems and dilemmas.** Consider how these should shape the curriculum, teaching and assessment so that every student develops sustainable values, competencies and intention to act, and no student is at a disadvantage. Take steps to ensure that no single perspective dominates ESD and that every student can find a personal connection with it.
+ **Engage with CPD.** Not all educators will become interdisciplinary ESD specialists. Those who do take this role will need to research the relationship between their own discipline, other disciplines and sustainability, and how to teach this to students. Of particular relevance to ESD is CPD around interdisciplinary team teaching, teaching sustainability competencies and values, stimulating and guiding critical reflection, identifying focusing questions and problems for students, teaching students methods for working in interdisciplinary groups and with external partners, facilitating project- and problem-based learning, managing emotion and maintaining hope, and developing a repertoire of teaching approaches associated with sustainability learning outcomes.

For leaders

+ **Define ESD** in ways which bring clarity to the terms used in outcomes such as skills, competencies or capabilities. Aim for an institution-wide shared understanding of these basic ESD concepts.
+ **Strategise to integrate ESD in core degree curricula.** To bring change, ESD needs to be approached as a recurring process through which students deepen their knowledge, values and competencies in systematic and holistic ways for the duration of their degree programme. This needs to be done in ways which do not compete for academic attention with disciplinary learning nor with other sector agendas such as careers, cultural competency, inclusivity, entrepreneurship and digital capabilities. An integrated approach to curriculum design is needed.
+ **Establish ESD as an institutional concern.** Much ESD currently depends on charismatic, motivated individuals and is vulnerable if those individuals move on. A 'whole university' approach encompassing all parts of the institution will help with integration and avoid hidden curricula where students pick up messages from the institution which conflict with what they are being formally taught about sustainability.
+ **Offer an institution-wide interdisciplinary sustainability course that reinforces students' degree specialisms.** For students whose core curriculum does not include ESD, an extra-curricular course may be their only opportunity to learn about sustainability at university. Extra-curricular courses are not associated with transformation in the publications we reviewed, but there are signs that they could be transformative if they are interdisciplinary, transdisciplinary and designed to reinforce each student's degree specialism. This also makes it possible for the course to be recognised as complementary and eventually adopted into degree programmes. To be credit-bearing, such a course will need an administrative home. To be transformative, its educators and leaders will need to be resourced to undertake the considerable work involved in inter- and transdisciplinary learning.
+ **Resource continuing professional development for sustainability educators and enable them to prioritise it.** CPD is considered a key driver for ESD. Educators facing competing priorities need permission and reason to treat the CPD as important and urgent, so that it is not the first thing to be sacrificed under pressure. Of particular relevance to ESD is CPD around interdisciplinary team teaching, teaching sustainability competencies and values, stimulating and guiding critical reflection, identifying focusing questions and problems for students, teaching students methods and techniques for working in interdisciplinary groups and with external partners, facilitating students project- and problem-based learning, managing emotion and maintaining hope, and developing a repertoire of teaching approaches associated with intended learning outcomes.

+ **Resource long-term research, development and evaluation to improve progress with ESD.** This will help to bring conceptual clarity to learning outcomes and galvanise the development of assessment instruments and practices. Of particular importance are long-term follow-up studies which draw connections between ESD teaching approaches, students' influence on sustainability in their communities and workplaces, and the consequences of this influence. This will shed light on demographic differences in how students respond to ESD, and feed back into curricula and teaching approaches.
+ **Reward interdisciplinarity.** Interdisciplinarity is essential to ESD. It needs to be appropriately resourced and valued in recruitment and promotion criteria. At the same time, it is important to maintain disciplinarity specialisms so that fruitful interactions can occur between them.
+ **Support educators through the challenges of disciplinary curriculum design.** Standardisation will not work here because, without educators' agency and personal engagement, the quality of education will degrade. Moreover, various professional bodies who accredit degrees will differently influence how ESD is addressed. At the same time, building consensus across disciplines can be time-consuming and not every educator can be expected to develop pedagogical familiarity with disciplines beyond their own. Consequently, to develop interdisciplinary and transdisciplinary curricula, universities need efficient, energy-conserving approaches to requirements gathering and consensus generation which involve all stakeholders while avoiding intensive, bottleneck-prone processes. Division of labour between disciplinary and interdisciplinary educational scholarship and teaching is possible.
+ **Enable work with external partners through capacity building and resource.** To realise the mutual transdisciplinary benefits of external partnerships, this review has underlined the need for expectation management, preparation, structure and close liaison for both the students and the partners. In some degree programmes – particularly those which are professionally oriented – work with external partners is already well-established and supported by dedicated placement team. In other disciplines, links and established ways of working with external partners do not yet exist and need to be resourced.
+ **Build capacity for central and faculty leadership, and support for change.** This entails deciding which aspects of ESD should be standard across an institution, which need a local or thematic focus, and which should be devolved for individual educators and students to interpret for their own context. This support should be formalised in strategy and policy.
+ **Incentivise programme and module leaders to make the transition.** ESD curricula are often open and differentiated, requiring constant calibration and intervention. This makes them demanding to design, set up and maintain. At the beginning ESD curricula typically require extra investment of time and energy. Unfamiliar pedagogies and ways of working may cost more initially until they bed down. The most transformative ESD courses are particularly effortful for the leaders of those programmes and courses, requiring coordination, monitoring, liaison and frequent intervention, particularly where there are external partners. There is a need to address the high workloads currently impeding educators' engagement with these potent approaches to ESD.

+ Enable large scale, valid and longitudinal approaches to evaluation. Follow-up evaluation will reveal the extent to which the effects of ESD diminish over time. Practical support from researchers or evidence-bringers specialised in educational research methods can relieve some of the pressure on individual educators to research and disseminate their own practice, and is likely to improve the quality and transferability of the evidence.
+ Incentivise dissemination. Disseminating ESD practice is vital to its progress, yet – outside Educational Studies departments - publishing on education is often peripheral to academic reward and recognition structures. Moreover, the demands of designing, teaching and sustaining ESD are likely to divert time and energy from researching and publishing about it. Support and recognition for contributing to the sum of what is known about ESD is therefore needed.
+ Engage with resistance. Addressing an increasingly mechanistic paradigm of education requires staff and students to value unsettling modes of teaching that are not always welcomed. It will also entail de-escalating competition and enabling cooperation within and between institutions. ESD is likely to advance further and more quickly where it works with the grain of existing strong disciplinary identities and missions. University leaders will play a major role in persuading their academic communities to commit to ESD and prioritise it.

For researchers

+ **Aim for conceptual clarity in ESD terminology.** Reviewers of ESD literature have found it difficult to know what is being researched since empirical publications frequently omit to define the intended learning outcomes of their interventions or how these can be recognised. To progress with ESD research, clarity is needed.
+ **Carry out large-scale, multi-institutional, well-contextualised explanatory research.** There is an abundance of case studies, but these do not readily lend themselves to generalisation. There is a need for well-contextualised research drawing causal connections between teaching approaches and sustainability outcomes.
+ **Carry out long-term follow-up studies.** ESD is dedicated to future action, yet there is a lack of follow-up research. It is important to know more about what students do with the sustainability knowledge, competencies, values and intentions to act. Under what circumstances do graduates achieve change in their workplaces and communities? What is the role of their education, and what factors are to do with the communities, workplaces and other external factors? What are the consequences of the action? These questions are hard to answer but necessary to pursue.
+ **Reduce reliance on self-reported learning or change as an evaluation approach.** It is one of the most available approaches to an under-resourced researcher, but it is compromised by social desirability bias and students' misjudgements. The publications reviewed offer very fleeting glimpses of theories which may be of use to discerning transition and epistemological development.

+ **Distinguish between academic assessment and educational evaluation.** If assessment is valid, it can contribute to evaluation. However, a primary purpose of academic assessment is to determine students' performance in relation to a desired standard. As such, assessment tends to be short term and oriented to learning outcomes. On its own it is unlikely to reveal causal relationships between curriculum design, teaching approaches and longer term sustainability outcomes. It is unlikely to say much about students' internal processes of integrating, knowledge, competencies, values and becoming ready and willing to act.
+ **Generate instruments and practices to assess sustainability learning.** Instruments such as rubrics can help students understand the nature of tasks which may otherwise be obscure, how to succeed and how to assess their own performance.

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Appendix – methods

Search strategy

To answer the questions above, we needed to distinguish education *for* sustainable development from the enormous volume of publications on sustainability in higher education that are not primarily concerned with ESD. We needed to avoid publications on sustainability of *teaching practices*; sustainable *institutions*, education *about* sustainability science without values and action, students' baseline *dispositions* toward sustainability without a focus on education, and measures to promote responsible citizenship or *consumer behaviour* alone. To exclude these from the search and isolate ESD we tied sustainability closely to education. This strategy summarised in Figure 9 was developed and peer reviewed by systematic review specialists in the university library and by academic members of our team.

Figure 9. Concepts and indicative search terms (here, for EBSCO searches)

Concept 1: ESD

"educat* for sustainab*" OR "learning for sustainab*" OR "sustainab* educat*" OR "Sustainab* development educat*" OR "sustainab* health* educat*" OR "sustainab* environment* educat*" OR "ESD Competenc*" OR "green competenc*" OR "core competenc* for sustainability" OR ESD OR ("climate change" N2 educat*)

Concept 2: Higher Education

universit* OR academi* OR college* OR "higher education" OR "post compulsory educat*" OR "tertiary educat*" OR "post secondary education" OR "medical school*" OR "nursing school*" OR "medical educat*" OR "business school*" OR degree* OR "grad* school*" OR "doctoral program*" or doctorate* OR "graduate diploma*"

Concept 3: impact

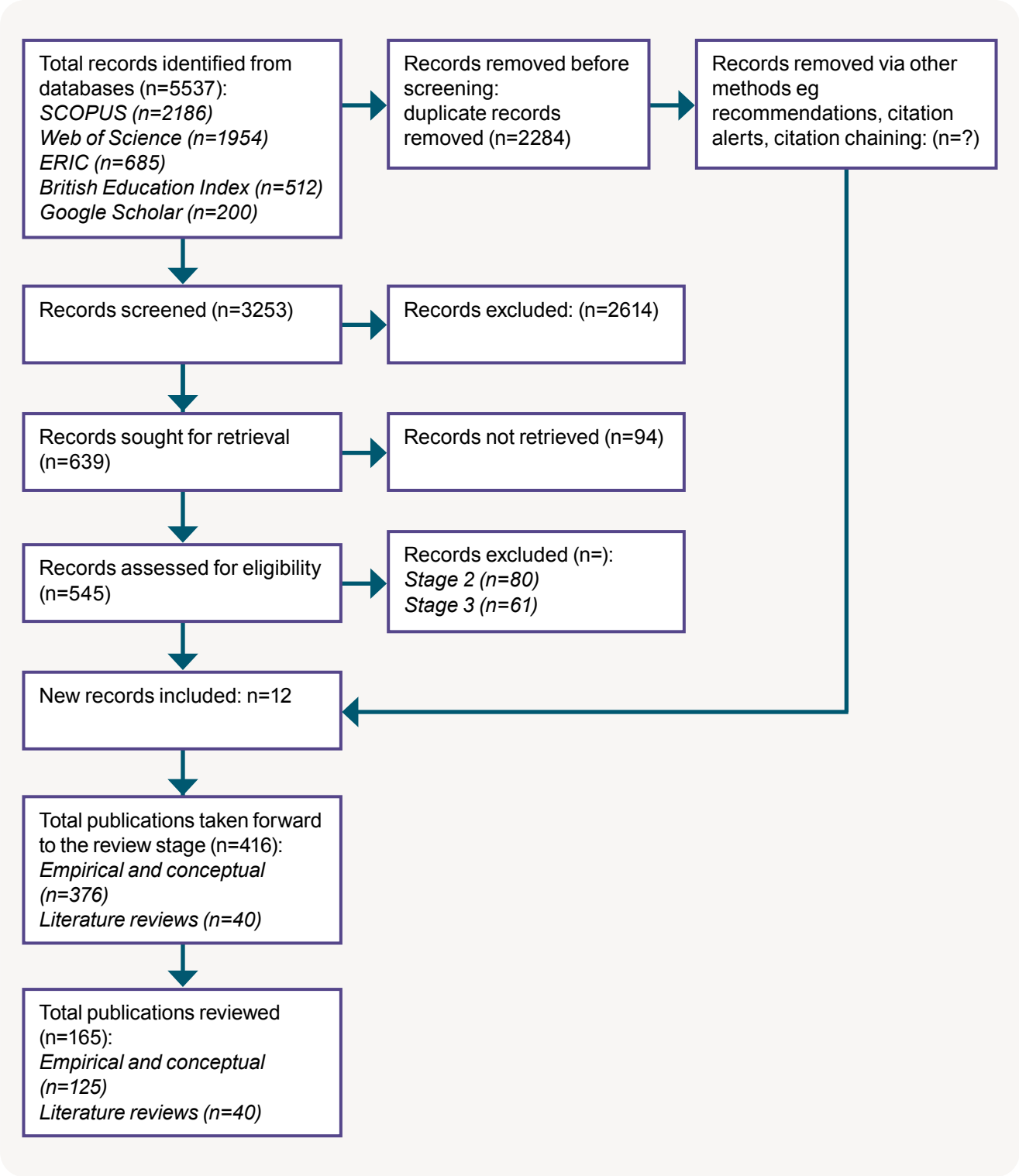
outcome* OR success* OR Employab* OR Impact* OR attain* OR confidence OR satisfaction OR experience OR "system thinking" OR anticipatory OR normative OR strategic OR collaboration OR "critic* think*" OR "self-aware*" OR "integrated problem-solving" OR competenc* OR values OR knowledge* OR "professional skill*" OR attitude* OR perception* OR career* OR leader* OR "sustainability role*" OR "sustainability minded"

On small specialist education databases (British Education Index, ERIC, Australian Education Index) we searched All Fields. On larger cross-disciplinary databases (SCOPUS and Web of Science) we searched Title, Abstract and Keywords. This strategy yielded the database totals in Figure 10. The database searches concluded on 4 November 2022 and a grey literature search was then conducted by searching Google Scholar and using citation chaining from a sample of the articles included in this review. We exported results to Zotero reference management software, where we deduplicated and exported again to a shared spreadsheet for screening.

Inclusion criteria

To screen this large dataset we used a three-stage filtering process related to our research questions and described in detail in 'Appendix – filtering criteria'. Four team members (MV, LP, XH and MOH) were involved with filtering, with three carrying out roughly one third each over several weeks. To improve reliability, team members participated in a calibration exercise and meetings to discuss difficult decisions. The project lead checked a sample of others' decisions, and differences were resolved through discussion. The process is reported in

Figure 10. Flow diagram of the inclusion process, based on adapted PRISMA guidelines (Page et al, 2021).



Data extraction

After filtering we had included 416 publications, a volume which exceeded our capacity and posed a dilemma about whether to review only the publications rated as most relevant to our research questions and with the most generalisability. This would entail excluding most of the studies we had given a midpoint rating, since they tended to be descriptive single cases. However, we were reluctant to exclude these since they are often richly specific and offer valuable insights which, taken together, make a valuable contribution. Noting this, we did our best to accommodate the volume by creating sub-categories within our midpoint relevance rating and reviewing all publications in the highest of these (three star high, as well as four star and five star). We also included some publications offering underrepresented perspectives. Of the 416 publications included, we had the capacity to review 165.

Fifty-six of the publications were literature reviews, 40 of which were included. The other reviews were filtered out or not prioritised for review, either because they were published early in our timeframe, were primarily concerned with bibliometric aspects or were broader than higher education. Literature reviews can be found in the second tab of the dataset spreadsheet.

Reviewing entailed reading each publication carefully and summarising background, context and findings, along with some bibliometric metadata used in previous ESD reviews (Barth and Rieckmann, 2016) and educational research (Cohen, Manion and Morrison, 2017). Using controlled vocabulary where possible, we noted curriculum context (embedded or extra-curricular), background, condensed findings, research focus (descriptive, exploratory, explanatory, conceptual according to Barth and Rieckmann, (2016)), research methods, disciplinary group (combinations of hard/soft, pure/applied according to the Becher-Biglan typology (Simpson, 2017). The same reliability measures were deployed as for filtering. A small amount of filtering decisions were revised at this stage either through discussion or (occasionally where a member had left the team) through the project lead's decision. There was some continuity between team members who filtered and those who reviewed the included publications (MV, LP and MOH were joined by JP and J-BG; XH left the project due to prior commitments). The next phase derived themes from the condensed findings. As noted in the section **'Error! Reference source not found.',** at this stage we managed the complexity of this literature by moving from a grounded approach to a more structured one, categorising our themes according to a curriculum design framework.

Appendix – full search strategy

On SCOPUS we trialled omitting ESD due to the number of results found where ESD was an acronym for Endoscopic Mucosal Resection but have elected to include ESD and remove irrelevant results during filtering to maintain consistency between databases.

On smaller databases (ERIC, the British Education Index and the Australian Education Index) we searched all fields. On larger databases we used narrower search parameters. On SCOPUS we searched the article title, Abstract and Keyword fields. On Web of Science we searched topic, or, title, abstract, author keywords and keywords plus. On Proquest Social Sciences Premium Collection we searched Anywhere except full text NOFT.

EBSCO searches (ERIC and BEI)

Concept 1 – ESD

“educat* for sustainab*” OR “learning for sustainab*” OR “sustainab* educat*” OR “Sustainab* development educat*” OR “sustainab* health* educat*” OR “sustainab* environment* educat*” OR “ESD Competenc*” OR “green competenc*” OR “core competenc* for sustainability” OR ESD OR (“climate change” N2 educat*)

Concept 2 – Higher Education

universit* OR academi* OR college* OR “higher education” OR “post compulsory educat*” OR “tertiary educat*” OR “post secondary education” OR “medical school*” OR “nursing school*” OR “medical educat*” OR “business school*” OR degree* OR “grad* school*” OR “doctoral program*” or doctorate* OR “graduate diploma*”

Concept 3 – impact

outcome* OR success* OR Employab* OR Impact* OR attain* OR confidence OR satisfaction OR experienc OR “system thinking” OR anticipatory OR normative OR strategic OR collaboration OR “critic* think*” OR “self-aware*” OR “integrated problem-solving” OR competenc* OR values OR knowledge* OR “professional skill*”OR attitude* OR perception* OR career* OR leader* OR “sustainability role*” OR “sustainability minded”

SCOPUS search

Concept 1 – ESD

“educat* for sustainab*” OR “learning for sustainab*” OR “sustainab* educat*” OR “Sustainab* development educat*” OR “sustainab* health* educat*” OR “sustainab* environment* educat*” OR “ESD Competenc*” OR “green competenc*” OR “core competenc* for sustainability” OR ESD OR (“climate change” W/2 educat*)

Concept 2 – Higher Education

universit* OR academi* OR college* OR “higher education” OR “post compulsory educat*” OR “tertiary educat*” OR “post secondary education” OR “medical school*” OR “nursing school*” OR “medical educat*” OR “business school*” OR degree* OR “grad* school*” OR “doctoral program*” or doctorate* OR “graduate diploma*”

Concept 3 – impact

outcome* OR success* OR Employab* OR Impact* OR attain* OR confidence OR satisfaction OR experienc OR “system thinking” OR anticipatory OR normative OR strategic OR collaboration OR “critic* think*” OR “self-aware*” OR “integrated problem-solving” OR competenc* OR values OR knowledge* OR “professional skill*”OR attitude* OR perception* OR career* OR leader* OR “sustainability role*” OR “sustainability minded”

Web of Science Core Collection

Concept 1 – ESD

“educat* for sustainab*” OR “learning for sustainab*” OR “sustainab* educat*” OR “Sustainab* development educat*” OR “sustainab* health* educat*” OR “sustainab* environment* educat*” OR “ESD Competenc*” OR “green competenc*” OR “core competenc* for sustainability” OR ESD OR (“climate change” NEAR/2 educat*)

Concept 2 – Higher Education

universit* OR academi* OR college* OR “higher education” OR “post compulsory educat*” OR “tertiary educat*” OR “post secondary education” OR “medical school*” OR “nursing school*” OR “medical educat*” OR “business school*” OR degree* OR “grad* school*” OR “doctoral program*” or doctorate* OR “graduate diploma*”

Concept 3 – impact

outcome* OR success* OR Employab* OR Impact* OR attain* OR confidence OR satisfaction OR experienc OR “system thinking” OR anticipatory OR normative OR strategic OR collaboration OR “critic* think*” OR “self-aware*” OR “integrated problem-solving” OR competenc* OR values OR knowledge* OR “professional skill*”OR attitude* OR perception* OR career* OR leader* OR “sustainability role*” OR “sustainability minded”

ProQuest Searches (AEI)

Concept 1 – ESD

“educat* for sustainab*” OR “learning for sustainab*” OR “sustainab* educat*” OR “Sustainab* development educat*” OR “sustainab* health* educat*” OR “sustainab* environment* educat*” OR “ESD Competenc*” OR “green competenc*” OR “core competenc* for sustainability” OR ESD OR (“climate change” NEAR/2 educat*)

Concept 2 – Higher Education

universit* OR academi* OR college* OR “higher education” OR “post compulsory educat*” OR “tertiary educat*” OR “post secondary education” OR “medical school*” OR “nursing school*” OR “medical educat*” OR “business school*” OR degree* OR “grad* school*” OR “doctoral program*” or doctorate* OR “graduate diploma*”

Concept 3 – impact

outcome* OR success* OR Employab* OR Impact* OR attain* OR confidence OR satisfaction OR experienc OR “system thinking” OR anticipatory OR normative OR strategic OR collaborat* OR “critic* think*” OR “self aware*” OR “integrated problem-solving” OR competenc* OR values OR knowledge* OR “professional skill*”OR attitude* OR perception* OR career* OR leader* OR “sustainability role*” OR “sustainability minded”

Google scholar

S1

Since 2015

All in Title

All of the words: “higher education”

At least one of the words ESD “education for sustainable development” “education for sustainability” “sustainability development education” “ESD competences” “core competences for sustainable development” “green competences”

Results: 555

Sorted by relevance

Downloaded: first 100

AND

S2

Since 2015

All in Title

All of the words: university

At least one of the words ESD “education for sustainable development” “education for sustainability” “sustainability development education” “ESD competences” “core competences for sustainable development” “green competences”

Results: 555

Sorted by relevance

Downloaded: first 100

Appendix – filtering criteria

Filter Stage 1: inclusion/exclusion criteria.

Instructions for Filter Stage 1:

1. Read the **title and abstract** of each publication that has been allocated to you.
2. Use the criteria in Table 1 to decide if that article should be included or excluded. If unsure, ask the project leader Mira (mira.vogel@kcl.ac.uk or use Teams chat).
3. In the filtering spreadsheet provided (you can find this in the same place as these instructions) find the record for that allocated article, record your decision from the drop-down list.
4. For articles you code as Include, proceed to Filter Stage 2.
5. For articles you code as Exclude, Report, About university educators, Literature Review, Thesis, or Interesting you don't need to complete further Filter Stages.

Table 4. Inclusion and exclusion criteria for Filter Method 1

Inclusion criteria (Stage 1)	Exclusion criteria (Stage 1)
All of the following: + English language or other language known to reviewers. + 1 Jan 2015 to present. + Focused on ESD in higher education curricula. + Focused on students' learning and/or outcomes (including student teachers). + Includes information about pedagogies, teaching strategies and/or assessments. + Empirical articles beyond purely conceptual focus.	Any of the following: + Pertaining to higher educators rather than students – if relevant please code as 'About university educators' educational development'. + Thesis or dissertation – if relevant, please code as 'Thesis'. + Literature reviews, meta-analyses – please code as 'Literature review'. + If not empirical but conceptually ground-breaking or clarifying, please code as 'Interesting'. + Language other than English, or language unknown to reviewers. + Before 2015. + Irrelevant to higher education. + Irrelevant to students' learning. + Conceptual articles that do not draw on empirical evidence.

Filter Stage 2: content relevance and application.

Studies still included after Filter Stage 1 will next be assessed based on the content, methodological alignment, and generalisability of the data.

+ **Content:** focus will be maintained on ESD pedagogies, practices, assessment designs or policies; how ESD is embedded in curricula across disciplines; and how ESD is enacted in subjects with agendas such as inclusivity, employability, enterprise, internationalisation and digital capabilities.
+ **Methods:** empirical studies, reviews and meta-analyses, which report on the educational context, participants, methods, and provide detailed findings, will be prioritised so that comparisons between studies can be made and the focus on learning outcomes maintained.
+ **Generalisability:** studies considered must bring insights that are transferable to different contexts, institutional cultures, and learning environments, to ensure that the data can inform the Advance HE's new ESD framework.

Instructions for Filter Stage 2:

1. **Read each publication** still included after carrying out Filter Stage 1. If you cannot get access to it, code it as Unobtainable.
2. Apply the criteria in Table 2. As before, if you're unsure, ask the project leader Mira (mira.vogel@kcl.ac.uk or use Teams chat).
3. As before, in the filtering spreadsheet provided find the record for each article, record your decision in the appropriate cell, and include a brief reason with reference to any relevant criteria below.
4. To save time re-reading, carry out Filter Stages 2 and 3 together.

Table 5. Criteria for Filter Method 2

Inclusion criteria (Stage 2)	Exclusion criteria (Stage 2)
Any of the following: + ESD policy development; + Institutional educational culture change; + Curriculum design; + Formulating or operationalising learning outcomes; + Assessment e.g. design; criteria development; + Learning activity design; + Analysis of ESD teaching, learning and/or assessment; + Analysis of student attainment; + Analysis relating ESD to social / behavioural change; + Review of ESD literature; + Meta-analysis of ESD research.	Any of the following: + Not pertaining to any of the inclusion criteria. + Unfocused on ESD in curricula e.g. pertaining to sustainable education, sustainable institutions, or education about rather than for sustainable development. + Limited to description or conceptual focus without empirical data analysis (if relevant, code as 'Interesting').

Filter Stage 3: ranking

The final stage involves applying a ranking criterion in Table 3 to the studies that satisfised Filter Method 2, to differentiate between the strengths and limitations of each study to understand which studies should be prioritised for review.

Instructions for Filter Stage 3:

1 For each article which is included after carrying out Filter Stage 2, apply the criteria in Table 3. As before, if you're unsure, ask the project leader Mira (mira.vogel@kcl.ac.uk or use Teams chat).

2 As before, in the filtering spreadsheet provided find the record for each article, record your decision in the appropriate cell, and include a brief reason – a sentence with reference to the criteria.

3 For any articles with 3 stars or more, add a link to the record (if no existing click-through exists already) – or if you have to download it, then save it in the 'Articles' folder

Table 6. Criteria for ranking in Filter Method 3

Star rating	Criteria
5*	Research questions directly relevant to this review. Empirical methods highly appropriate, multiple (affording triangulation), well-executed, and reported fully and clearly. Findings relate aspects of curriculum design to student outcomes and attainment. Findings relate to all or most of: students' perceptions of learning; measures of learning; engagement; self-confidence; progression; satisfaction. Findings give attention to student diversity. The size and disciplinary diversity of the population studied provides good indication about transferability of findings.
4*	Research questions well-aligned with this review. Empirical methods appropriate, well-executed, and reported fully and clearly. Findings relate to some or most of: curriculum design, student outcomes and attainment; perceptions of learning; measures of learning; engagement; self-confidence; progression; satisfaction. The size and disciplinary diversity of the population studied provides some indication about transferability of findings.
3*	At least one relevant research question. Empirical methods appropriate, well executed and reported fully and clearly. Findings relate to at least one of: curriculum design; student outcomes and attainment; perceptions of learning; engagement; self-confidence; progression; satisfaction. The population studied is small and/or not diverse, so provides limited indication about transferability of findings but there is some substantiated discussion about transferability.
2* and below	Excluded – irrelevant research questions, lack of clarity about methods and/or findings, small, homogeneous population studied, and little or no substantiated insights about transferability of findings.

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