Empathy and Education for Sustainable Development: An overview of key publications and implications for engineering education

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Abstract
The engineering skills required for the 21st century and the green transition go beyond technical knowledge. Sustainability problems are multidimensional and require consideration of multiple perspectives. Empathy plays a fundamental role in enabling the development of more humanistic and socially constructed skills required to act for sustainability. It is an essential element of human-centred design and ethical behaviour, as well as engineering teamwork, engagement with diverse stakeholders, and ability to work in intercultural settings. Engineers must relate to the needs of the primary user and empathise with those (in)directly affected by their decisions. This highlights the importance of helping engineering students cultivate and apply empathy. However, little research has explored the influence of students' empathy on education outcomes for sustainable development.
The paper presents an overview of key publications in education for sustainable development (ESD) - the first step of a state-of-the-art review which is part of a larger study on empathic engineering education for sustainable development. The overview is guided by the research question "How is empathy described and framed in current sustainable education policies and frameworks?". The paper provides a time-framed overview of the current policies and educational frameworks and identifies directions for future work on embedding empathy in engineering education for sustainable development.

Keywords: sustainable development, empathy, engineering education, review

1 Introduction

The United Nations' Sustainable Development Goals (SDGs) were established in 2015 as a response to the urgent and global environmental, social, and economic challenges and built on the lessons learned from the Millennium Development Goals (MDGs), which were in place from 2000 to 2015. The SDGs have important implications for engineering and engineering education, as engineering plays a critical role in addressing many of the complex global challenges the world is currently facing. Engineers are essential in developing sustainable solutions for issues such as clean energy, water and sanitation, infrastructure, and climate change. Consequently, engineering education must equip future engineers with the knowledge, skills, and ethical grounding necessary to contribute effectively to sustainable development. This education goes beyond providing technical expertise – integrating the SDGs into engineering education involves embedding principles of sustainability, ethics, and social responsibility into the curriculum. This includes fostering interdisciplinary collaboration, promoting a holistic understanding of the societal impacts of engineering decisions, and encouraging empathy and engagement with diverse stakeholders. It requires an appreciation of various perspectives and an understanding of individuals' backgrounds and experiences.

The competences required for the 21st century and the green transition go beyond technical knowledge (Beagon et al. 2022). They span across different disciplines and bring to the fore the ability to collaborate with multiple stakeholders, consider different perspectives, and understand people with diverse backgrounds and experiences (Segal, 2018). In this sense, empathy plays a fundamental role in enabling the development of more humanistic and socially constructed competences required to act for sustainability.

In engineering education, the focus on sustainability has led to a body of initiatives focused on tackling global challenges. However, most of the engineering programs focus exclusively on technical solutions and tend to overlook the interpersonal and social dimensions of sustainable development (Andrade & Tomblin, 2018). Today, more than ever, engineers need empathy to address the 21st-century global challenges. Empathy – the ability to understand a person from his or her frame of reference rather than one's own, their feelings,

perceptions, and thoughts – is an essential element of human-centred design and ethical behaviour, as well as of effective work in teams, engagement with diverse stakeholders, and ability to work in intercultural settings. Alarmingly, studies show a decrease in engineering students' interest in public welfare over the course of their education (Cech, 2014), with students being less 'person-oriented' compared to practicing engineers (Bairaktarova & Pilotte, 2020). Empathy, which involves understanding others from their viewpoint, is essential for cultivating the humanistic and socially constructed skills necessary for sustainability. It is integral to human-centred design, ethical conduct, teamwork, stakeholder engagement, and working in intercultural environments. In sustainable design, engineers must empathize with both the primary users and those indirectly impacted by their decisions, as sustainability challenges are complex and require consideration of multiple viewpoints. However, despite the importance of empathy, little research has explored the influence of students' empathy on education outcomes for sustainable development. The current paper describes a study that is part of a larger research project on empathic engineering education for sustainable development. It presents an initial overview of empathy and sustainable education. This overview will inform a larger state-of-the-art review guided by two research questions: RQ1. "How is empathy described and framed in current sustainable education policies and frameworks?" and RQ2. "What empathy approaches and interventions are used in engineering education?". This state-of-the-art review will provide a time-framed review of the current policies, educational frameworks, and identifies to inform directions for future work on embedding empathy in engineering education for sustainable development. The overview presented in this paper addresses RQ1.

2 Literature review

2.1 Education for Sustainable Development (ESD)

Education for Sustainable Development (ESD) is an educational approach that aims to empower learners with knowledge, skills, values and attitudes to address interconnected global issues such as climate change, biodiversity loss, poverty and inequality (UNESCO, 2024a). It has been led by UNESCO (United Nations Educational, Scientific and Cultural Organization) since the United Nations Decade of Education for Sustainable Development (from 2005 to 2014), and then followed by the Global Action Programme (from 2015 to 2019). In 2019, UNESCO proposed a new framework for ESD, covering the period between 2020 to 2030 – the ESD for 2030 (UNESCO, 2020).

ESD is focused on the integration of sustainability principles throughout learning processes. As an educational approach, ESD encompasses three learning domains - cognitive, socio-emotional, and behavioural. Climate change education, and a broader approach encapsulated in the concept of greening education, are important elements of ESD. ESD is an element of SDG 4, Quality Education, target 4.7, "By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development" (United Nations, n.d.) with the following indicators "Extent to which (i) global citizenship education and (ii) education for sustainable development are mainstreamed in (*a*) national education policies; (*b*) curricula; (*c*) teacher education and (*d*) student assessment".

These frameworks emphasize the importance of equipping future engineers with the skills and knowledge necessary to address complex global challenges related to sustainability. For example, engineering programs now embed sustainability principles through innovative teaching approaches like challenge-based learning (CBL) and interdisciplinary collaboration. This includes teaching students about sustainable design, renewable energy, resource management, and the social and environmental impacts of engineering

decisions. Moreover, accreditation bodies such as EUR-ACE and ABET have revised their requirements to include sustainability competencies. Engineering programs are now required to demonstrate how they prepare students to contribute to sustainable development. This has prompted institutions to align their educational objectives with sustainability goals, ensuring that graduates possess the necessary skills to address sustainability challenges.

Education for sustainable development in engineering education has benefited from interdisciplinary collaborations that focus on ethical and social responsibility. Sustainability issues are multifaceted and require input from different disciplines to understand the interconnectedness of social, economic and environmental factors better. At the same time, considering the needs and perspectives of multiple stakeholders is essential for understanding how engineering decisions could have direct or indirect impacts on them (Bairaktarova et al., 2024). This requires a human-centred approach for developing sustainable solutions.

Empathy plays a pivotal role in these human-centred approaches, enabling engineers to genuinely understand the needs, concerns, and perspectives of diverse stakeholders affected by their work. By developing empathic capabilities, engineers can better anticipate the social and environmental impacts of their designs, identify potential unintended consequences, and create solutions that truly serve community needs rather than merely technical requirements. This empathic foundation facilitates more inclusive decision-making processes and ultimately leads to more equitable, contextually appropriate, and sustainable outcomes.

2.2 Empathy

In engineering education, empathy has emerged as a critical component of professional development, particularly in its connection to ethical decision-making and responsible practice (Hess et al. 2021; Strobel et al., 2013). While engineering has traditionally emphasized technical competence, growing recognition of the social impacts of engineering work has led to increased attention to empathy as a core professional skill (Walther et al, 2017). Notably, most studies have relied upon definitions of interpersonal empathy, as suggested by the frameworks which have been mostly used for empathy measurement in EER (Baligar, et al., 2024).

In the context of sustainable design, engineering students must not only relate to the needs of the primary user but also empathize with those indirectly affected by their decisions (Lehtonen et al., 2019). Sustainability problems are multidimensional and require consideration of multiple perspectives (Lönngren et al., 2016). Empathy is the foundational ‘people skill’ needed more than ever in engineering education for sustainable development. However, to date, little research has explored the influence of students’ empathy on the outcomes of sustainable education.

The larger study, of which this overview is one of the foundational steps, will use Elizabeth Segal's concept of Social Empathy, which extends beyond interpersonal empathy (which includes affective response, affective mentalizing, self-other awareness, perspective-taking, and emotion regulation) to include contextual understanding and macro-perspective taking (Segal, 2018—two components essential for sustainability education). Social empathy involves understanding the lived experiences of people and communities different from our own, recognizing the impact of historical, structural and systemic factors. This broader perspective taking, applied to larger social groups and communities, can help build positive engagement (Segal, 2018). Segal's social empathy framework provides a more comprehensive approach to understanding the broader social, economic, and environmental systems, making it particularly relevant for addressing complex sustainability challenges.

3 Methodology

State-of-the-art reviews aim to present a comprehensive coverage of the existing literature on more current matters and are usually presented in a narrative format but can also make use of tables. They are particularly useful for identifying potential new avenues for research (Booth et al., 2012; Grant & Booth, 2009). In this overview, and to identify relevant and current frameworks and policies in education for sustainable development, we searched the publication databases of two main organisations: The European Union, as the research project involves two European universities; and the United Nations. We considered documents that were explicit about frameworks, competencies and skills required for ESD 2020-2030, and that were published after 2019. The following documents and reports were included in this stage:

3.1 UNESCO Greening curriculum guidance

This guidance was designed to help individuals, institutions and organizations promote a holistic approach to climate change and sustainability education, for different age groups. It draws on the Education for Sustainable Development (ESD) for 2030 framework and offers guidance on how to integrate climate change into the educational curriculum at all levels of education and across all subjects – it's a foundational tool for greening education. The main part of this document includes key concepts, topics and learning outcomes for different age groups, ranging from K-12 to 18+. Despite its focus on climate change, the document "follows a holistic approach with climate change as the entry point to addressing environmental, social and economic aspects of sustainable development (UNESCO, 2024b, p.21). Greening education is organised in six key concepts with respective topics and learning outcomes, as listed in Table 1.

Table 1. Greening education key concepts

Key concept	Topics
1. Climate science	1.1. Weather, climate and climate change 1.2. Greenhouse gases 1.3. The carbon cycle 1.4. The water cycle 1.5. Avoiding pollution and conserving resources 1.6. Renewable energy
2. Ecosystems and biodiversity	2.1. Natural environment: ecosystems and biodiversity 2.2. The evolution of biodiversity over time and in the future 2.3. Ecosystems, biodiversity and ecosystem services 2.4. Human relation to nature: domestication and agriculture 2.5. Human-induced biodiversity loss and its consequences 2.6. Reconnecting to nature and protecting it
3. Climate justice	3.1. Contemporary manifestations 3.2. Social determinants 3.3. Historical economic and political processes 3.4. Transformed futures
4. Resilience-building	4.1. Social impacts of climate change 4.2. Navigating climate impacts: strategies for safety and resilience 4.3. Climate anxiety and constructive coping 4.4. Strength and interconnectedness 4.5. Urgency and community action 4.6. Tacking climate mis/disinformation
5. Post-carbon economies	5.1. Economic growth and development 5.2. The circular economy and everyday life

		5.3. Climate change and our economies 5.4. Energy consumption and carbon emissions 5.5. Our roles in a post-carbon economy
6.	Sustainability lifestyles	6.1. Engagement with nature 6.2. Renewable energy use 6.3. Responsible consumption 6.4. Sustainable living spaces 6.5. Sustainable mobility 6.6. Sustainable diets 6.7. Sustainable waste practices

3.2 The Inner Development Goals

The Inner Development Goals framework was launched in 2022 to address the slow progress towards achieving the Sustainable Development Goals (SDGs). While the SDGs offer a comprehensive framework for tackling global sustainability issues, the IDGs recognize that achieving these goals requires more than just technical or policy solutions. It requires a different mindset focusing on attitudes, values and skills of human growth and development that lead to change effectively. The framework includes five dimensions (Being, Thinking, Relating, Collaborating, Acting) with a total of 23 skills (IDG, 2021).

3.3 GreenComp – the European sustainability competence framework

To help promote learning on environmental sustainability, the European Union (EU) published the GreenComp – a framework that identifies a set of sustainability competences. It aims "to help learners develop knowledge, skills and attitudes that promote ways to think, plan and act with empathy, responsibility, and care" for the planet and public health (Bianchi et al, 2022). The GreenComp is organized in 4 areas, which one with 3 competences:

1. Embodying sustainability values: 1.1. Valuing sustainability; 1.2. Supporting fairness; 1.3. Promoting nature
2. Embracing complexity in sustainability: 2.1. Systems thinking; 2.2. Critical thinking; 2.3. Problem framing
3. Envisioning sustainable futures: 3.1. Futures literacy; 3.2. Adaptability; 3.3. Exploratory thinking
4. Acting for sustainability: 4.1. Political agency; 4.2. Collective action; 4.3. Individual initiative

3.4 UNESCO Education for Sustainable Development – a roadmap

This publication builds on the previous roadmap for 2015-2019 (Global Action Programme), and outlines UNESCO's steps in addressing sustainable development challenges through education in five main areas: advancing policy, transforming learning environments, building capacities of educators, empowering and mobilizing youth, and accelerating local level actions. In this document, ESD is considered to be critical to address SD4 (Quality Education), in particular of target 4.7, "By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development" (UNESCO, 2020, p.14).

4 Findings

4.1 UNESCO Greening curriculum guidance

In this document, empathy is clearly stated as a key competence for sustainability, part of a broader *collaboration competency*, "the abilities to learn from other; to understand and respect the needs, perspectives and actions of others (empathy); to understand, relate to and be sensitive to others (empathic leadership); to deal with conflicts in a group; and to facilitate collaborative and participatory problem-solving" (UNESCO, 2024b, p.182). Empathy as social and emotional learning was referenced multiple types for education of pre-18 individuals. For 18+ it was mentioned in two specific suggested activities:

- Topic 4.2. Navigating climate impacts: strategies for safety and resilience. "Key idea: there are specific activities than we can undertake for emergency responses risk reduction, mitigation and adaptation". At a social and emotional dimension, "learners should be able to enhance empathy for communities especially vulnerable to climate impacts and understand the importance of collective action in keeping everyone safe" (UNESCO, 2024b, p.109).
- Topic 4.3. Climate anxiety and constructive coping. "Key Idea: It is important to work together in addressing climate anxiety". At a social and emotional dimension, "learners should be able to demonstrate qualities like resilience, hope, empathy and assertiveness, essential for leadership in the face of climate challenges" (UNESCO, 2024b, p. 111).

4.2 The Inner Development Goals

The skill *empathy and compassion* is placed under *Relating – Caring for Other and the World*, as is defined as the "ability to relate to others, oneself and nature with kindness, empathy and compassion and the intention to address related suffering (…) Empathy here is understood to be the capacity to relatively accurately understand and feel into what other people feel, whereas compassion adds the quality of wanting to relate to other people with benevolence." (IDG, 2021, p.19). The framework includes other skills related to definitions of empathy, such as *perspective skills* (*Thinking – Cognitive Skills*), "skills in seeking, understanding and actively making use of insights from contrasting perspectives" (IDG, 2021, p.16), and *self-awareness* (*Being – Relationship to Self*), "ability to be in reflective contact with own thoughts, feelings and desires; having a realistic self-image and ability to regulate oneself" (IDG, 2021, p.14). Other skills were suggested to be associated with empathy and compassion in the framework, namely *connectedness* (*Relating*) "having a keen sense of being connected with and/or being a part of a larger whole, such as a community, humanity or global ecosystem" (IDG, 2021, p.18), *humility* (*Relating*), "being able to act in accordance with the needs of the situation, without concern for one's own importance" (IDG, 2021, p.19).

4.3 GreenComp – the European sustainability competence framework

'Empathy' is mentioned explicitly in competence *promoting nature* (1.3), which "is about developing empathy towards the planet and showing care for other species" (Bianchi et al, 2022, p.18), and as an attitude "shows empathy with all life forms" (Bianchi et al, 2022, p.42).It was also mentioned in competence problem framing (2.3) as a key attitude, "listens actively and shows empathy when collaborating with others to frame current and potential sustainability challenges" (Bianchi et al, 2022,p.22 and p.45). Moreover, Empathy is one of the 9 lifelong learning skills and is defined as one of the attitudes to develop 'Problem framing': "listens actively and shows empathy when collaborating with others to frame current and potential sustainability challenges" (Bianchi et al, 2022, p.22).

4.4 UNESCO Education for Sustainable Development – a roadmap

Empathy, along with solidarity and action-taking, is identified as a key competence in ESD, "Its (ESD) particular emphasis on competencies related to empathy, solidarity and action-taking can help advance SDG 4 towards the future where education contributes not only to the successes of individuals, but also to the collective survival and prosperity of the global community" (UNESCO, 2020, p.14). In the roadmap, empathy

is placed under the *social and emotional learning dimension* of ESD, with the other dimensions being cognitive learning and behavioural learning. The social and emotional learning dimension is defined as "build core values and attitudes for sustainability, cultivate empathy and compassion for other people and the planet, and motivate to lead the change" (UNESCO, 2020, p. 17). One of the reflections of the framework for the implementation of ESD is the need for transformative action, "An experiential exposure to the realities provides them (learners) with a deeper connection with the issue, which can also lead to an empathic connection to those affected by the said realities. Empathy can turn into compassion if the exposed realities bear relevance to the learners' own lives and their sense of identity" (UNESCO, 2020, p.57).

5 Discussion

Our analysis underscores the critical role of empathy in addressing the multifaceted challenges of sustainable development. Existing frameworks often provide a narrow understanding and conceptualization of empathy, focusing predominantly on its emotional and relational aspects. However, empathy encompasses significant cognitive, social, emotional and behavioural dimensions that are essential for a comprehensive approach to ESD. This perspective aligns with Segal's multi-component definition of social empathy – a transformative framework that expands interpersonal empathy into social justice. According to Segal (2011, 2018), empathy must include structural awareness, recognizing how history, culture, public policies, political attitudes, and social structure shape our capacity for empathy. Moreover, social empathy is associated with pro-social behaviour, political reform and collective action aimed at reducing inequality, positionings it as a powerful tool (Segal, 2011, 2018; Sochacka et al., 2021; Howcroft & Mercer, 2022, 2024; Howcroft et al., 2025).

UNESCO (2020) emphasises that education should: (i) equip learners with values, attitudes and behaviours for sustainability; (ii) promote transformative learning, including empathy and systems thinking; and (iii) cultivate interpersonal skills to collaboratively address global challenges. Empathy is increasingly recognized as a core competency in engineering education for sustainable development (ESD), especially when aligned with global frameworks like UNESCO's ESD Roadmap and the IDGs**.** Their emphasis on empathy-related skills can help promote SDG 4, in which education contributes not only to individual success but also to collective survival and prosperity. At the same time, there is a shift from a narrow focus on access and quality—often measured through learning outcomes—toward a broader emphasis on learning content and its contribution to social and planetary sustainability. In this way, ESD connects SDG 4 with all other SDGs (UNESCO, 2020).

According to Segal's framework (2011, 2018) and UNESCO's Agenda (2019, 2020, 2024a, 2024b), empathy is crucial to address the global education agenda envisioned by SDG 4, in which ESD occupies a prominent place. It is aligned with UNESCO's priority areas for action, as suggested in Table 2.

Table 2. Empathy and UNESCO's priority areas

Priority Area	Role of Social Empathy
Advancing Policy	Empathy informs inclusive, human-centred policies
Transforming Learning	Enables participatory, experiential education
Empowering and Mobilization of Youth	Build interpersonal networks through understanding others and their social-historical contexts

Engineering solutions inevitably have an impact on people and ecosystems. By incorporating empathy into engineering education, we can ensure that future engineers are better equipped to understand the diverse

needs of stakeholders; design inclusive, ethical, and sustainable technologies; and consider the long-term social and environmental implications of their work. Empathy is a critical skill for the 21st century engineers, as it enhances a deeper understanding of users' needs, foster creativity, and supports the development of ethical reasoning (Howcroft & Mercer, 2024; De Zoysa et al., 2024; Howcroft et al., 2025). Despite its importance, empathy-based pedagogies remain an underexplored area within engineering education research (Howcroft & Mercer, 2024).

While a few initiatives have embedded empathy within engineering curricula (e.g., Walther et al., 2017; Sochacka et al., 2021; Howcroft & Mercer, 2022, 2024), further opportunities exist to integrate *social empathy*—a deeper and more nuanced understanding of systemic inequalities and diverse lived experiences—into pedagogical frameworks. Such integration is essential for cultivating engineers as socially responsible change agents. Adopting definitions of social empathy, as proposed by Segal (2018), can enhance our understanding and application of empathy in educational contexts. This approach aligns with the *Greening Curriculum Guidance*, which emphasizes the importance of exploring the "sociopolitical and psychosocial dimensions of climate change is crucial for cultivating green life skills such as empathy" (UNESCO, 2024b, p.28).

For engineering education, this implies a need for more research on theories and models of empathy towards the planet. Understanding how empathy can be integrated into engineering curricula will help future engineers develop the skills necessary to address global sustainability challenges. Researchers and practitioners must examine their own institutions' experiences and practices to identify knowledge gaps and opportunities for improvement. Collaborative and cooperative studies are essential for advancing the field of engineering education. By sharing insights and strategies, the broader community can work together to foster a more holistic and empathic approach to sustainable development. This collective effort will not only enhance educational outcomes but also contribute to a more sustainable and equitable future.

Acknowledgements

This work is part of the project "Empathic engineering education for sustainable development", funded by Fundação para a Ciência e a Tecnologia (FCT): https://doi.org/10.54499/2023.13074.PEX

References

Andrade, N. A., & Tomblin, D. (2018, June), *Engineering and Sustainability: The Challenge of Integrating Social and Ethical Issues into a Technical Course* Paper presented at 2018 ASEE Annual Conference & Exposition , Salt Lake City, Utah. 10.18260/1-2—30402

Bairaktarova, D. N., & Pilotte, M. K. (2020). Person or thing oriented: A comparative study of individual differences of first-year engineering students and practitioners. *Journal of Engineering Education, 109*(2), 230–242. https://doi.org/10.1002/jee.20309

Bairaktarova, D., Bloemen, V., Direito, I., & Van Maele, J. (2024). "I've learned that behind every headline there is a human with their story": Gearing up engineering design projects for nurturing empathy. Proceedings of the 52nd Annual Conference of SEFI, Lausanne, Switzerland. https://doi.org/10.5281/zenodo.14256781

Baligar, P., Amashi, R., M, V., Chen J., Guerra, A., & Du, X. (2024). Review on empathy in engineering education: Conceptions, interventions and challenges. REES 2024 https://www.proceedings.com/content/073/073963-0012open.pdf

Beagon, U., Kövesi, K., Tabas, B., Nørgaard, B., Lehtinen, R., Bowe, B., Gillet, C., & Spliid, C. M. (2023). Preparing engineering students for the challenges of the SDGs: What competences are required? *European Journal of Engineering Education, 48*(1), 1–23. https://doi.org/10.1080/03043797.2022.2033955

Bianchi, G., Pisiotis, U., & Cabrera Giraldez, M. (2022). *GreenComp: The European sustainability competence framework*, Punie, Y. and Bacigalupo, M. editor(s), EUR 30955 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-76-46485-3, doi:10.2760/13286, JRC128040.

Booth, A., Papaioannou, D., & Sutton, A. (2012). *Systematic approaches to as successful literature review*. SAGE Publications.

Cech, E. A. (2014). Culture of Disengagement in Engineering Education? *Science, Technology, & Human Values, 39*(1), 42–72. https://doi.org/10.1177/0162243913504305

De Zoysa, R., Male, S., & Chapman, E. (2024). Motivation and the role of empathy in engineering work. *Australasian Journal of Engineering Education*, *29*(1), 55–65. https://doi.org/10.1080/22054952.2024.2346410

Grant, M. J., & Booth, A. (2009). A typology of reviews: An analysis of 14 review types and associated methodologies. *Health Information & Libraries Journal*, *26*(2), 91–108. https://doi.org/10.1111/j.1471-1842.2009.00848.x

Hess, J. L., Miller, S., Higbee, S., Fore, G. A., & Wallace, J. (2021). Empathy and ethical becoming in biomedical engineering education: A mixed methods study of an animal tissue harvesting laboratory. *Australasian Journal of Engineering Education, 26*(1), 127–137. https://doi.org/10.1080/22054952.2020.1796045

Howcroft, J., & Mercer, K. (2022). Where We Are: Understanding Instructor Perceptions of Empathy in Engineering Education. *Proceedings of the Canadian Engineering Education Association (CEEA)*. DOI: 10.24908/pceea.vi.15913.

Howcroft, J., & Mercer, K. (2024). Instructor and Graduate Student Perspectives: Is Empathy a Needed Design Skill for Future Engineers? *2024 ASEE Annual Conference & Exposition Proceedings 'The of Engineering Education'.* Oregon Convention Center, Portland, OR, June 23-26. DOI: 10.18260/1-2--47639

Howcroft, J., Vale, J., Kirkscey, R., & Mercer, K. (2025). Empathy in Engineering Students – Initial Assessment of Student Perceived Ability. *Proceedings of the Canadian Engineering Education Association (CEEA)*. https://doi.org/10.24908/pceea.2025.19716

Inner Development Goals (IDG) (2021). *Inner Development Goals: Background, Method and the IDG Framework* https://drive.google.com/file/d/13fcf9xmYrX9wrsh3PC3aeRDs0rWsWCpA/edit

Lehtonen, A., Salonen, A. O., & Cantell, H. (2019). Climate Change Education: A New Approach for a World of Wicked Problems. In J. W. Cook (Ed.), *Sustainability, Human Well-Being, and the Future of Education* (pp. 339–374). Springer International Publishing. *https://doi.org/10.1007/978-3-319-78580-6_11*

Lönngren, J., Svanström, M., Ingerman, Å., & Holmberg, J. (2016). Dealing with the multidimensionality of sustainability through the use of multiple perspectives – a theoretical framework. *European Journal of Engineering Education, 41*(3), 342–352. https://doi.org/10.1080/03043797.2015.1079811

Segal, E.A. (2011). Social Empathy: A Model Built on Empathy, Contextual Understanding, and Social Responsibility That Promotes Social Justice. *Journal of Social Service Research, 37:3*, 266-277, DOI: 10.1080/01488376.2011.564040

Segal, E.A. (2018). Social Empathy: The art of understanding others. Columbia.

Sochacka, N., Delaine, D., Shepard, T., & Walther, J. (2021). Empathy Instruction Through the Propagation Paradigm: A Synthesis of Developer and Adopter Accounts. *Advances in Engineering Education.*

Strobel, J., Hess, J., Pan, R., & Wachter Morris, C. A. (2013). Empathy and care within engineering: Qualitative perspectives from engineering faculty and practicing engineers. *Engineering Studies, 5*(2), 137–159. https://doi.org/10.1080/19378629.2013.814136

UNESCO (23 October 2024a). What you need to know about education for sustainable development. Retrieved 10 March 2025, from https://www.unesco.org/en/sustainable-development/education/need-know

UNESCO (2024b). Greening curriculum guidance: teaching and learning for climate action. https://doi.org/10.54675/AOOZ1758

UNESCO (2020). Education for sustainable development: a roadmap. https://doi.org/10.54675/YFRE1448

UNESCO (2019). Framework for the implementation of education for sustainable development (ESD) beyond 2019. Retrieved 31 March 2025, from https://unesdoc.unesco.org/ark:/48223/pf0000370215.locale=en

United Nations (n.d). United Nations, Sustainable Development Goals. Goal 4: Targets and Indicators, Retrieved 21 March 2024, from https://sdgs.un.org/goals/goal4#targets_and_indicators

Walther, J., Miller, S. E., & Sochacka, N. W. (2017). A Model of Empathy in Engineering as a Core Skill, Practice Orientation, and Professional Way of Being: A Model of Empathy in Engineering. *Journal of Engineering Education, 106*(1), 123–148. https://doi.org/10.1002/jee.20159