Design and Technology Education: An International Journal

28.2

The Place of Design Education in Achieving 4IR Sustainability through the 4Cs Skill-sets

Peter Oluwagbenga Odewole, Olabisi Onabanjo University, Nigeria
Tolulope Oladimeji Sobowale, Olabisi Onabanjo University, Nigeria
Festus Osarumwense Uzzi, Olabisi Onabanjo University, Nigeria

Abstract

The Fourth Industrial Revolution (4IR) merges the physical, digital, and biological spheres, reshaping societies and individuals worldwide in unprecedented ways. With the fast-moving globalization and rapid rate of technological development of the 4IR, the world is also facing unprecedented social, economic, and environmental challenges. As the 4IR continues to reshape industries across the globe, there is an increasing need for educational systems to adapt and equip students with the necessary skills to thrive in this rapidly evolving landscape. With its diverse socio-economic context and pressing environmental concerns, a specific emphasis on design education is required to develop a skilled workforce capable of driving sustainability in the 4IR. Given the needs of the 4IR, students need to possess a set of skills that are highly sought after. These skills, commonly known as the "4Cs," encompass communication, creativity, critical thinking, and collaboration. Design education plays a substantial role in preparing students for the demands of the 4IR, as it cultivates a holistic and interdisciplinary approach to problem solving, innovation, and sustainable development. This paper explores the place of design education in nurturing the 4Cs skill sets for achieving 4IR sustainability, focusing on how design education can address the unique challenges and opportunities faced in the 4IR era.

Keywords

Design Education, 4IR Sustainability, 4Cs Skill-sets, Design Thinking

Introduction

With the fast-moving globalization and rapid rate of technological development of the fourth industrial revolution (4IR), the world is also facing unprecedented social, economic, and environmental challenges (Schleicher, 2018). Therefore, while there is a sense of urgency to adopt 4IR technologies, adequate learning is required to achieve sustainable development in the 4IR era in such a way as to provide services for improving the quality of life (Ally & Wark, 2019). The Industrial Revolutions, including the IR, 2IR, 3IR, and the ongoing 4IR, emerged due to advancements in science, technology, and societal culture, each driven by the goal of enhancing the quality of human life. Design thinking, as obtainable in design education, served as a veritable tool for driving the technological innovations of the first, second, and third industrial revolutions (1IR, 2IR, and 3IR) and even the most recent 4IR (Adelabu, Akinbogun & Odewole, 2019).

The 4IR is characterized by innovations transforming activities in all sectors of human activities, generated by the convergence of emerging technologies such as big data and analytics, cloud computing, artificial intelligence (AI), internet of things (IoT), robotics, virtual and augmented reality, and more (Kasza, 2019). However, despite the 4IR technologies' immense potential,

they also create concerns about the future, given that they could exert increased pressure on the earth, its resources, and human life (Zervoudi, 2019). Consequently, it is imperative to take necessary measures through education to fully harness the potential of the 4IR to transform the world, improve the well-being of individuals, and open up new avenues for global sustainable development, thereby expediting progress towards a sustainable future (Tejedor, et al., 2022). With sustainability in mind, it is evident that design education has a more critical role in the fourth industrial revolution than in all the previous eras. Skill sets required to prepare a workforce that can be sustained during the 4IR have been identified to include workforce readiness and soft, technical, and entrepreneurship skills (Armstron et al., 2018). Since the design field promotes skill-based learning, a key challenge in the 4IR is to explore approaches that promote societal and environmental sustainability by sharpening the required skill sets in the students before graduation. By identifying the significance of design education in developing the required skills for 4IR sustainability, students can proactively prepare for the challenges and opportunities presented by this transformative era.

Identifying barriers to effective design education in the context of 4IR sustainability is crucial for overcoming challenges and ensuring that students receive the necessary knowledge and skills to thrive in this rapidly evolving landscape. Incongruent with the challenges of education for sustainable development and constraints of education for the 4IR (Education 4.0), the main barriers that may hinder effective design education in the 4IR sustainability context include outdated curricula and a lack of resources or expertise in emerging technologies (Leicht, et al., 2018; Constan et al., 2021). These may impede students' ability to acquire the necessary skills to address sustainability issues in the 4IR. Since the 4IR is characterized by exponential technological advancements such as artificial intelligence, robotics, and automation, keeping up with these rapid changes and incorporating them effectively into design education can be challenging. Obstacles to interdisciplinary collaboration, such as rigid academic structures, limited opportunities for cross-disciplinary interaction, and the lack of integrated curriculums, can impede effective design education in the 4IR sustainability context (Leicht, et al., 2018; Constan et al., 2021). Limited access to vital resources, such as state-of-the-art technology, materials, and tools, particularly in educational institutions with financial constraints, can hinder students' ability to explore innovative and sustainable design solutions (Leicht, et al., 2018; Constan et al., 2021). A lack of engagement and collaboration between educational institutions and industry partners can hinder students' exposure to real-world challenges and limit their understanding of industry expectations and practices (Ankrah & AL-Tabbaa, 2015). This can result in limited opportunities for internships and industry projects that restrict students' ability to develop practical skills and gain industry insights relevant to 4IR sustainability. Resistance to change among educators and students can be a barrier (Sun & Turner, 2022). Overcoming deeply ingrained traditional design practices and fostering a sustainability mindset may require comprehensive educational reforms, educator professional development opportunities, and targeted awareness campaigns (Riel et al., 2015; Conway, Leahy, & McMahon, 2021).

In the 4IR era, individuals must have the necessary skills and competencies to thrive and contribute effectively to sustainable development. With the right skills in place, students can embrace the potential of the 4IR, contribute to innovation, and create sustainable solutions that address societal, economic, and environmental challenges. Design education's role in developing these skill sets is crucial for achieving a sustainable and inclusive future in the 4IR

era. The 4Cs skills - communication, creativity, critical thinking, and collaboration - are essential for thriving in the 4IR context and achieving the Sustainable Development Goals (SDGs) (Ruminar & Gayatri, 2018). By nurturing the development of the 4Cs skills, design education equips individuals with the tools and mindset needed to tackle complex sustainability challenges in the 4IR. By cultivating critical thinking, interdisciplinary collaboration, empathy, and technological proficiency, design education prepares students to address the complex challenges and opportunities of the 4IR while driving sustainable development. A comprehensive understanding of design education's role in developing the 4Cs skill sets can pave the way for a more sustainable and prosperous future in the 4IR era. Design education promotes design thinking, which prepares students to become adaptable, empathetic, and innovative problem solvers who can navigate the evolving landscape of technology, society, and sustainability (Charles, 2022). Therefore, this article aims to explore in-depth how the 4Cs skills are integral to achieving sustainability goals within the 4IR context, how design education and design thinking foster the development of the 4Cs skills, and how relevant models and theories can be adopted for improving the 4Cs skills in design education for ensuring 4IR sustainability.

Methodology

Using an integrative literature review, the study establishes the place of design education in achieving 4IR sustainability through the 4Cs skill sets. According to Snyder (2019), the primary goal of an integrative review is to evaluate, analyze, and combine existing literature pertaining to a specific research subject, facilitating the emergence of novel theoretical frameworks and perspectives. The study followed the systematic steps typical of an integrative review, which encompassed formulating one or more review questions, pinpointing all relevant electronic databases and sources for exploration, constructing a well-defined search strategy, scrutinizing titles, abstracts, and articles against predetermined inclusion and exclusion criteria, and systematically extracting data from chosen literature in a standardized format (Toronto, 2020).

The research questions for this study are as follows: (i) How can the 4Cs skill-sets help in achieving sustainability in the 4IR era? (ii) How can design education promote the development of the 4Cs skills needed for 4IR sustainability? (iii) What is the significance of design thinking towards advancing 4IR sustainability? (iv) What are the relevant theories and models that may be adopted to improve 4Cs skills in design education for 4IR sustainability? To answer these questions, a university database search engine and Google Scholar web search engine were used to identify potential articles. Searches were conducted on the database to identify relevant studies using the following terms: “design education” AND “4IR”, “design education” AND “SDGs,” “4Cs skills” AND “SDGs,” “design thinking” AND “sustainable development goals,” "academia and industry collaboration in the 4IR”, communication” AND “SDGs,” “creativity” AND “SDGs,” “critical thinking” AND “SDGs,” “collaboration” AND “SDGs,”.” This procedure yielded results considered as the initial samples.

After incorporating the specified keywords, the following inclusion and exclusion criteria were considered for selecting the final sample: the articles must be a peer-reviewed journal publication in English, accessible through university-subscribed or open-access journal databases, and have titles, abstracts, and full-texts that are directly related to the study. Publications that failed to meet these criteria were excluded. A comprehensive full-text analysis of these articles was then performed to determine their relevance to the research questions under consideration, resulting in a final sample of articles used in the study.

The 4Cs Skill Sets for 4IR Sustainability

The core of the United Nations' 2030 Agenda comprises 17 Sustainable Development Goals (SDGs) introduced in 2015 (Rieckmann et al., 2017; Halkos & Gkampoura, 2021). Table 1 shows the summary of the 17 SDGs (United Nations, 2015). These goals aim to tackle social, economic, and environmental issues to ensure a sustainable, peaceful, prosperous, and equitable life for the present and future generations (Rieckmann et al., 2017; Halkos & Gkampoura, 2021).

Table 1. The 17 Sustainable Development Goals (SDGs)

Number	Description	Objective
SDG 1	No Poverty	End poverty in all its forms everywhere.
SDG 2	Zero Hunger	End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.
SDG 3	Good Health and Well Being	Ensure healthy lives and promote well-being for all at all ages.
SDG 4	Quality Education	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
SDG 5	Gender Equality	Achieve gender equality and empower all women and girls.
SDG 6	Clean Water and Sanitation	Ensure availability and sustainable management of water and sanitation for all.
SDG 7	Affordable and Clean Energy	Ensure access to affordable, reliable, sustainable, and clean energy for all.
SDG 8	Decent Work and Economic Growth	Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.
SDG 9	Industry, Innovation and Infrastructure	Build infrastructure, promote inclusive and sustainable industrialization, and foster innovation.
SDG 10	Reduced Inequalities	Reduce inequality within and among countries.
SDG 11	Sustainable Cities and Communities	Make cities and human settlements inclusive, safe, resilient, and sustainable.
SDG 12	Responsible Consumption and Production	Ensure sustainable consumption and production patterns.
SDG 13	Climate Action	Take urgent action to combat climate change and its impacts.
SDG 14	Life below Water	Conserve and sustainably use the oceans, seas, and marine resources for sustainable development.
SDG 15	Life on Land	Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation, and halt biodiversity loss.
SDG 16	Peace, Justice, and Strong Institutions	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.
SDG 17	Partnership for the Goals	Strengthen the implementation and revitalize the global partnership for sustainable development

The challenge in the future lies not in a lack of employment opportunities but rather in a scarcity of the skills required for the new jobs that will emerge (Ruminar & Gayatri, 2018). This observation emphasizes the importance of developing the necessary skills to ensure sustainability in the 4IR context. The 4Cs skills can play a crucial role in advancing the SDGs by enabling individuals and organizations to think critically, communicate effectively, collaborate efficiently, and develop innovative solutions to address the complex challenges of sustainable development. These skills are interrelated and can be applied to various aspects of the SDGs, making them essential tools for achieving global goals. By recognizing the interconnectedness

of the 4Cs skills and the SDGs, students can actively contribute to sustainable development. According to Thornhill-Miller et al. (2022), the 4Cs skills should not be viewed as entirely independent components but rather as interconnected fundamental "elements" for forward-thinking education, which can support individuals in their learning journey and, when combined, have a synergistic effect, enabling the growth of their cognitive abilities. Honing the 4Cs skills will empower students to foster a culture of creativity/critical thinking and promote collaborative initiatives to thrive in the 4IR era while working toward realizing the SDGs.

Communication Skills.

Effective communication is vital for promoting the SDGs (Genç, 2017; Khairil et al., 2018; Oueiss & El-Khoury, 2023). Individuals can raise awareness about sustainable development issues by articulating ideas, advocating for change, and engaging with diverse stakeholders. Communication skills are instrumental in fostering dialogue, mobilizing support, and facilitating collaborations among different sectors of society to work towards the SDGs. Since intricate and unpredictable factors generally mark sustainability-related concerns, effective communication is crucial in disseminating information among various stakeholders to ensure business success (Genç, 2017). Communication skills can contribute to SDG 4 (Quality Education) by promoting effective communication and information sharing in educational settings, ensuring inclusive access to education for all. Communication skills enable individuals to convey ideas, concepts, and solutions effectively. In the 4IR, where diverse stakeholders collaborate across borders and disciplines, communicating clearly and persuasively becomes paramount to achieving the SDGs (Armstron et al., 2018; Mhlanga & Moloi, 2020).

Creativity Skills

Creativity and innovation have emerged as crucial factors for success in the twenty-first century, vital in driving organizational achievements across various sectors (Shu, et al., 2020). Creativity is a powerful driver for sustainable development (Awan, Sroufe, & Kraslawski, 2019; Nakao & de Andrade-Guerra, 2019; d'Orville, 2019; Mróz & Ocetkiewicz, 2021). According to d'Orville (2019), creativity has emerged as a significant catalyst in the current knowledge and learning economy era, propelling society toward sustainability through its remarkable ability to imagine and envision transformative possibilities. By thinking innovatively and outside traditional approaches, individuals can develop new solutions to address complex challenges related to poverty, inequality, climate change, and more. Creative thinking can lead to the development of sustainable technologies, eco-friendly practices, and inclusive business models that contribute to achieving the SDGs (Falvey, 2018; d'Orville, 2019; Awan, Sroufe, & Kraslawski, 2019). Creativity is relevant to SDG 9 (Industry, Innovation, and Infrastructure) by driving the development of sustainable technologies and fostering innovation in industries that promote economic growth and job creation. To effectively address the complex and uncertain nature of sustainability challenges, it is essential to possess capabilities for creativity and innovation rather than relying solely on skills focused on repeating existing practices and ideas (Sandi, 2013). Creativity is the driving force behind innovation and problem solving (Sandri, 2013; Chiruguru, 2020; Mróz & Ocetkiewicz, 2021; Ibeh, et al., 2023). In the 4IR sustainability context, creative thinking is crucial for designing sustainable solutions that balance economic, social, and environmental considerations.

Critical Thinking Skills

Critical thinking is vital in the 4IR, where technological advancements introduce new challenges and ethical dilemmas. Critical thinking skills are essential for analyzing the multifaceted issues surrounding sustainable development (Minott, et al., 2019; Kaur, 2021; Taimur & Sattar, 2019). Individuals who can evaluate information critically and assess the social, economic, and environmental implications of decisions are better equipped to make informed choices that align with the SDGs. Critical thinking also helps identify potential trade-offs and balance competing priorities in pursuing sustainable development. Critical thinking is needed when evaluating the efficacy of interventions, strategies, projects, and policies, especially when assessing the SDGs' accomplishment (Schwandt et al., 2016; Taimur & Sattar, 2019). Critical thinking is indispensable for everyone responsible for achieving the SDGs (Schwandt et al., 2016; Straková & Cimermanová, 2018; Chiruguru, 2020). Critical thinking skills are essential for analyzing complex problems, evaluating information, and making informed decisions. Critical thinking skills are germane in designing solutions to achieve all the 17 SDGs to terminate poverty, safeguard the planet, and guarantee inclusive prosperity.

Collaboration Skills

Collaboration is central to addressing the multifaceted challenges of sustainability in the 4IR. No single discipline or individual can tackle these complex challenges alone in isolation (Braßler & Sprenger, 2021). By fostering collaboration among governments, businesses, civil society organizations, and communities, individuals can pool resources, expertise, and knowledge to find sustainable solutions. Collaborative sustainability-oriented innovations generate benefits that influence various aspects of value creation, encompassing intrinsic and extrinsic dimensions (Stibbe et al., 2018; Mariani et al., 2022). Collaboration through interdisciplinary teamwork has been recognized as crucial for driving sustainable development (Braßler & Block, 2017; Velásquez, et al., 2023). The challenges associated with achieving the targets of the SDGs are intricate and cannot be effectively addressed within the confines of a single discipline (Braßler & Block, 2017; Hackett, 2020; Braßler & Sprenger, 2021). Instead, they necessitate collaboration across different fields of expertise. By integrating sustainability and interdisciplinary collaboration, a comprehensive understanding of these complex issues can be attained, leading to the discovery of practical solutions (Braßler & Block, 2017; Enechi & Pattberg, 2020; Stuart & Mataix, 2021; Higgins & Smith, 2022). Collaboration plays a central role in SDG 17 (Partnerships for the Goals), as it encourages cross-sector collaboration and international cooperation to mobilize resources, build capacity, and accelerate progress towards all SDGs. Collaborative approaches enhance collective problem solving, promote social cohesion, and create synergies that accelerate progress toward the SDGs.

How Design Education develops the 4Cs Skills for 4IR Sustainability

Design education nurtures effective communication by encouraging students to articulate their thoughts visually, verbally, and in written form (Zande, 2011; Cezzar, 2020). Communication is a crucial part of any design process, and any shortcomings in design communication can result in delays, errors, and even the ultimate failure of the entire process (Eckert, et al., 2005; Sandeep et al., 2021). The designer's typical objective involves communicating a specific design proposal using one or more drawings, which provide a comprehensive view of the artifact and specific details. Design education cultivates creativity by encouraging students to explore multiple perspectives, challenge assumptions, and think beyond conventional boundaries (Zande, 2011; Rosen, et al., 2020; Zhongbin, 2023). The primary purpose of design education is to harness the

innate creative abilities of individuals and foster the development of innovative products in intellectual, social, and cultural domains (Kilicaslan & Ziyrek, 2012; Daskova et al., 2020). It provides opportunities for experimentation, risk-taking, and exploring new materials, technologies, and design methodologies. Design education fosters critical thinking by teaching students to question, analyze, and evaluate information from multiple sources, encouraging them to consider the broader implications of their designs, such as their environmental impact, social equity, and long-term sustainability (Keane & Keane, 2019; Zhongbin, 2023).

Design education encourages collaboration and interdisciplinary approaches (Zande, 2011; McDermott, et al., 2014; Kaygan & Demir, 2017; Cohen & Mule, 2019; Petrova et al., 2022). Design education promotes collaboration by providing opportunities for interdisciplinary projects, teamwork, and stakeholder engagement. It encourages students to work collaboratively, leverage diverse perspectives, and embrace the collective problem-solving approach. By fostering interdisciplinary collaborations, design education enables students to tackle systemic challenges and create sustainable solutions considering a society's diverse needs and contexts. Collaboration enhances the effectiveness and impact of design solutions, fostering a holistic approach to 4IR sustainability. Design education instills a sense of empathy and social responsibility (Zande, 2011; López-León & Valdez, 2017; Bosch, Härkki & Seitamaa-Hakkarainen, 2022). Students are encouraged to consider their design decisions' social and environmental implications. This awareness is crucial for 4IR sustainability, where issues such as inequality, poverty, and environmental degradation are prevalent. By emphasizing ethical and sustainable design practices, students can contribute positively to society and drive change toward a more inclusive and environmentally conscious future.

Design Thinking and 4IR Sustainability

Design education nurtures design thinking, a powerful tool for fostering innovation and problem-solving abilities in the 4IR era. Design thinking is a human-centered problem-solving methodology that encourages creative and innovative solutions (Lor, 2017). Through design thinking methodologies, students learn to identify problems, empathize with users, and prototype innovative solutions. According to Lor (2017) analysis of the application of a design-thinking framework, design thinking can promote 4IR sustainability by adopting an empathy and a user-centric approach, developing an iterative and experimental mindset, encouraging multidisciplinary collaboration, stimulating creativity and ideation, and emphasizing human-centered prototyping and testing.

Design thinking ensures that user insights drive innovation, starting with understanding the end-users' needs, perspectives, and experiences and empathizing with the people for whom the solutions are intended (Deepa, 2020; Wible, 2022). This approach is especially relevant in the 4IR era, where technology transforms interactions between humans and systems. Design thinking enables individuals to identify significant problems, develop user-centric solutions, and enhance the overall user experience, embracing an iterative and experimental problem-solving approach (Foster, 2019; Deepa, 2020; Wible, 2022). Instead of pursuing a linear path, design thinkers develop prototypes and test their ideas early and frequently. This iterative process allows for feedback, learning, and refinement. In the 4IR era, where technologies evolve rapidly, an iterative mindset helps individuals adapt and respond to changing circumstances, fostering agility and resilience to face uncertainties.

Design thinking stimulates creative thinking and idea generation, providing a structured framework to explore new possibilities, challenge assumptions, and break away from conventional thinking (Deepa, 2020; Wible, 2022). This creative approach is essential in the 4IR era, where innovation is a crucial driver of success. Design thinking encourages individuals to embrace ambiguity, explore unconventional solutions, and unlock their creative potential to address emerging challenges and leverage technological advancements (Abell & DeVore, 2017). Design thinking emphasizes the creation of tangible prototypes to bring ideas to life, which are then tested and refined based on user feedback (Deepa, 2020; Wible, 2022). By involving users early in the process and incorporating their insights, design thinking ensures that solutions are relevant, effective, and user-friendly. This approach is valuable in the 4IR era, where technology can be complex and rapidly evolving since prototyping and testing allow individuals to validate ideas, identify potential issues, and iterate on their solutions to optimize outcomes.

Design thinking encourages collaboration across disciplines and diverse perspectives. It brings together individuals with different expertise, backgrounds, and knowledge to generate a rich pool of ideas and solutions. Collaboration is essential in the 4IR era, where complex challenges often require diverse skill sets. By fostering interdisciplinary collaboration, design thinking enables the synthesis of different perspectives, leading to more comprehensive and innovative solutions. By employing empathy, experimentation, collaboration, creativity, and human-centric prototyping, design thinking enables individuals to navigate the complexities of the 4IR landscape, develop innovative solutions that address societal needs, and leverage emerging technologies. Embracing design thinking as a mindset and integrating it into educational and organizational contexts can empower individuals to thrive in the 4IR by fostering a culture of creativity and innovation, adaptability, user-centered problem solving, and the ability to anticipate and navigate emerging technologies and societal shifts, all of which are fundamental for sustainable development in the 4IR.

Theories and Model to Improve 4Cs Skills in Design Education for 4IR Sustainability

Social Learning Theory and Social Cognitive Theory

The Social Cognitive Theory, developed in 1986, evolved from the Social Learning Theory (SLT) developed by Albert Bandura in 1960 (Koutroubas & Galanakis, 2022), offer valuable insights into how design education can apply its principles to acquire the 4Cs skills (Critical thinking, Creativity, Collaboration, and Communication) needed for the 4IR sustainability. The Social Learning Theory posits that learning occurs through observation, imitation, and social interaction (Lyons & Berge, 2012; Koutroubas & Galanakis, 2022). Design education can leverage Social Learning Theory by promoting collaborative projects, peer learning, and mentorship, allowing students to acquire and refine their 4Cs skills through interactions with peers, instructors, and professionals.

The Social Cognitive Theory highlights the importance of observational learning, where individuals acquire new knowledge, behaviours, and skills by observing others (Koutroubas & Galanakis, 2022). The theory highlights the reciprocal interaction between individuals, their environment, and their cognitive processes, providing a framework for understanding how design education can foster the development of these essential skills. In the context of design education, students can benefit from observing and modeling the behaviours and skills of experienced designers, mentors, and industry professionals. By providing opportunities for

students to witness real-world design processes, collaboration, and effective communication, design education can enhance the 4Cs skills by exposing students to successful role models (Starčič & Lebeničnik, 2020).

The Social Cognitive Theory emphasizes the role of self-efficacy, which refers to an individual's belief in their ability to perform a specific task (Koutroubas & Galanakis, 2022). Design education can enhance students' self-efficacy in the 4Cs skills by providing scaffolded learning experiences, constructive feedback, and opportunities for success. By gradually increasing the complexity of design tasks and providing support and recognition for students' achievements, design education can help students build confidence and competence in critical thinking, creativity, collaboration, and communication. The theory underscores the importance of self-regulation, which involves setting goals, monitoring progress, and adjusting behaviours to achieve desired outcomes (Bandura, 1991). In design education, students can be encouraged to set goals for their learning and design projects, monitor their progress, and reflect on their strategies and outcomes. By promoting self-regulation, design education supports the development of students' metacognitive skills, enabling them to effectively plan, monitor, and evaluate their use of the 4Cs skills in designing sustainable solutions for the 4IR.

The Social Cognitive Theory recognizes the influence of environmental factors on individual learning and behaviour, emphasizing the importance of social interaction and learning from others (Govindaraju, 2021). Design education can create an environment that supports the development of the 4C skills by providing collaborative spaces, tools, and resources for students to engage in meaningful design projects. By fostering a culture of collaboration, open communication, and interdisciplinary interactions, design education can facilitate the development of the 4Cs skills in response to the complex sustainability challenges of the 4IR. Design education can foster social learning by promoting collaborative design projects, group discussions, and peer feedback. By providing opportunities for students to engage in collaborative problem-solving, design education supports the development of the 4Cs skills in the context of teamwork, negotiation, and effective communication.

Experiential Learning Theory

Experiential Learning Theory (ELT), developed by David Kolb in 1984, provides a valuable framework for understanding and applying design education principles to acquire the 4Cs skills needed for 4IR sustainability. The Experiential Learning Theory suggests that learning occurs through a cycle of concrete experiences, reflection, abstract conceptualization, and active experimentation (Kolb & Kolb, 2005). The theory emphasizes the importance of hands-on experiences, reflection, and active engagement in the learning process, offering insights into how design education can foster the development of these essential skills. Experiential learning can be integrated into design education to enhance the acquisition of 4Cs skills by providing hands-on experiences and opportunities for critical thinking, creativity, collaboration, and communication.

The theory suggests that learning is most effective based on concrete experiences (McCarthy, 2010). In design education, concrete experiences mean providing students with authentic, real-world design challenges and projects related to 4IR sustainability. By engaging in concrete experiences, students can apply the 4Cs skills in practical contexts. This allows a deeper understanding of how these skills contribute to sustainable design practices. The Experiential

Learning Theory emphasizes the importance of reflective observation, which involves stepping back and carefully observing one's experiences and the experiences of others (McCarthy, 2010). Design education can incorporate structured reflection activities, such as journaling, group discussions, or critique sessions, to encourage students to reflect on their design processes, outcomes, and the impact of their work on sustainability. This reflective observation helps students refine their critical thinking skills, gain insights into their creative processes, improve collaboration, and develop effective communication strategies.

The theory suggests abstract conceptualization, which means that individuals must make sense of their experiences by transforming them into abstract concepts and theories (McCarthy, 2010). In design education, students can engage in critical analysis, concept mapping, and theory development related to 4IR sustainability. By abstract conceptualization, students deepen their understanding of the underlying principles and theories that guide sustainable design practices, enhancing their critical thinking skills and fostering creative problem-solving. The ELT highlights the importance of active experimentation, which involves applying new knowledge and skills to solve problems and create innovative solutions (McCarthy, 2010). Design education can provide opportunities for students to engage in prototyping, testing, and iterative design processes. By actively experimenting, students develop their creative thinking skills, learn from failures and successes, collaborate in problem-solving activities, and communicate their design ideas effectively to stakeholders.

The theory recognizes learning as a cyclical process involving concrete experience, reflective observation, abstract conceptualization, and active experimentation (Kolb & Kolb, 2005; Radović et al., 2021). Design education can incorporate iterative cycles of learning and practice, allowing students to revisit and refine their understanding of the 4Cs skills in the context of 4IR sustainability. This cyclical learning process encourages continuous improvement, adaptability, and the integration of the 4Cs skills into students' design practice. The Experiential Learning Theory encourages authentic assessment, which involves evaluating students' capabilities based on real-world performance and applying skills (Radović et al., 2021). Authentic assessment recognizes students applying the 4Cs skills in real-world contexts, promoting their ability to contribute to sustainable design practices in the 4IR. Design education can incorporate authentic assessment methods like project-based assessments, portfolio reviews, or stakeholder presentations. By assessing students' abilities to demonstrate the 4Cs skills in authentic contexts, design education ensures the alignment between acquiring these skills and their practical application in 4IR sustainability challenges.

T-shaped Skills Model

The T-shaped skills model provides a practical approach to design education to acquire the 4Cs skills needed for 4IR sustainability. The T-model was developed from the “T-shaped” concept coined by David Guest to describe the technologically proficient employees that would be essential in the near future (Garner & Estry, 2017). The model represents a combination of deep expertise in a specific domain (vertical bar of the "T") and a breadth of interdisciplinary skills and knowledge (horizontal bar of the "T") (Saviano et al., 2016). Design education can focus on developing the vertical bar of domain-specific skills while fostering the horizontal bar of interdisciplinary skills, including the 4Cs skills, to prepare students for 4IR sustainability challenges. The T-shaped skill set has been described as the most desirable for designers (Dekoninck & Bridge, 2023). The "T-shaped" conceptual representation of a designer's expertise

entails broad knowledge of related professions horizontally and in-depth knowledge of design processes vertically (Baratta, 2017).

The model emphasizes the significance of possessing profound expertise in a particular field (represented by the vertical bar of the "T") while also highlighting the capacity to collaborate and communicate effectively across various fields (illustrated by the horizontal bar of the "T"), providing valuable insights into how design education can promote the cultivation of these essential skills. The vertical bar of the T-shaped skills model represents the depth of knowledge in a specific area. In design education, students should develop a strong foundation of knowledge in design principles, theories, and practices relevant to 4IR sustainability. This includes understanding the principles of sustainable design, technological advancements, and the social, economic, and environmental implications of the 4IR. Building this depth of knowledge allows students to critically analyze complex problems, think creatively, and develop innovative solutions. The horizontal bar of the T-shaped skills model represents the ability to collaborate and communicate across different disciplines. Design education should encourage students to collaborate in interdisciplinary teams, engaging with engineering, social sciences, technology, and business professionals. By collaborating with diverse stakeholders, students develop collaboration and communication skills, appreciate different perspectives, and understand sustainability challenges in the 4IR.

The model underscores the significance of cross-disciplinary knowledge, which involves understanding and integrating concepts and practices from multiple disciplines. In design education, students should be exposed to various disciplines relevant to 4IR sustainability, such as data analytics, renewable energy, social impact assessment, and user-centered design. This cross-disciplinary knowledge enables students to apply critical thinking and creativity to bridge gaps between disciplines, facilitating the development of innovative and sustainable design solutions. The model aligns well with design thinking principles and a human-centered problem-solving approach. The model recognizes the importance of effective communication and presentation skills. Design education should allow students to develop their communication skills, including visual communication, written and oral presentation skills, and storytelling techniques. By effectively communicating their design ideas, students can engage stakeholders, build consensus, and convey their sustainable design solutions' social and environmental benefits in the 4IR.

The model acknowledges the need for lifelong learning and adaptability in the rapidly changing landscape of the 4IR. Design education should foster a culture of continuous learning, encouraging students to stay updated with emerging technologies, new design methodologies, and evolving sustainability practices. By nurturing a mindset of lifelong learning, design education equips students with the ability to adapt to new challenges and acquire additional skills as needed, ensuring their continued relevance in the 4IR (Keane & Keane, 2019). The T-model equips students with the necessary abilities to survive and flourish in a complex and challenging world, where adaptability, innovation, and transcend boundaries are crucial for success (Garner & Estry, 2017).

Recommendation

Design education should consider the interdisciplinary nature of the 4IR and encourage students to collaborate with individuals from various fields, such as engineering, computer

science, and social sciences. This interdisciplinary approach will enable them to understand their designs' broader implications and applications and create holistic, sustainable, and adaptable solutions. Implementing interdisciplinary approaches in design education is essential, as this can significantly enhance the learning experience and prepare students for the diverse and complex challenges of the 4IR era. Interdisciplinary education encourages the integration of knowledge, methods, and perspectives from multiple disciplines, fostering a holistic understanding and fostering creativity and innovation. Implementing interdisciplinary approaches in design education helps students bridge disciplinary gaps, promoting innovation, providing integrated learning experiences, and cultivating flexibility and adaptability.

In the 4IR era, there is a need to encourage cross-cultural and diverse perspectives in design education to foster creativity, inclusivity, and a deeper understanding of global design challenges. This can be achieved by engaging teaching faculties from various cultural backgrounds and design disciplines can expose students to different design practices, philosophies, and creative processes; and by facilitating student exchanges and collaborations with design schools and universities worldwide to create opportunities for students to engage with different cultures and design traditions. Students must be encouraged to participate in collaborative projects with international partners that will enable them to consider diverse perspectives, understand cultural nuances, and develop cross-cultural communication and collaboration skills. Cultural awareness and sensitivity training must be incorporated into the design curriculum. It helps students appreciate diverse cultural practices, beliefs, and values, equipping them with the needed knowledge and skills to approach design challenges from a culturally sensitive and inclusive standpoint. By accommodating diversity and incorporating cross-cultural perspectives, design education prepares students to become culturally sensitive and inclusive designers who can navigate a multicultural world and create solutions that resonate with diverse audiences.

Conclusion

To ensure a prosperous and inclusive future, educational institutions and policymakers must prioritize integrating design education within the broader educational framework, empowering students to become agents of positive change in the 4IR era. Design education prepares individuals to thrive in the 4IR era by equipping them with the necessary skills, fostering a sustainability mindset, and encouraging interdisciplinary collaboration. By embracing these principles, design education can contribute to shaping a future that harnesses the potential of the 4IR while addressing the pressing needs of our global community. To tackle the 4IR challenges, it is crucial to explore innovative approaches within design education that impart technical expertise and promote the development of skills that contribute to a sustainable society and environment. This includes fostering creativity, critical thinking, collaboration, and problem-solving abilities among students. By integrating these aspects into design education, future professionals can be empowered to address the complex social, economic, and environmental issues of the 4IR. Design education incorporates design thinking methodologies emphasizing empathy, iterative prototyping, and user-centered design processes. By adopting a design thinking mindset, students learn to approach complex sustainability challenges in the 4IR with critical thinking, creativity, and a collaborative spirit, leading to innovative and sustainable design solutions.

In the light of Social Learning Theory and Social Cognitive Theory, by leveraging observational learning, promoting self-efficacy and self-regulation, considering environmental factors, facilitating vicarious experiences, and fostering social learning, design education can create an effective learning environment that supports the development of the 4C skills in the context of sustainable design practices for the 4IR. The Experiential Learning Theory provides a comprehensive framework for design education to acquire the 4Cs skills needed for 4IR sustainability by incorporating concrete experiences, reflective observation, abstract conceptualization, active experimentation, and a cyclical learning process to foster the development of the 4Cs skills. The T-shaped skills model provides a comprehensive approach to design education to acquire the 4Cs skills needed for 4IR sustainability. In line with the T-shaped skills model, by combining depth of knowledge with collaboration, interdisciplinary skills, cross-disciplinary knowledge, design thinking, communication, and adaptability, design education prepares students to effectively address complex sustainability challenges and contribute to advancing sustainable design practices in the 4IR era.

It is noteworthy that not only individual students need to focus on design education for skill development but also educational institutions, governments, and businesses. Educational institutions should adapt design education into their curricula to incorporate 4IR-related subjects and foster skill-based learning approaches. Governments should prioritize investing in design education and training initiatives that equip individuals with the necessary skills for the 4IR workforce. Businesses should actively provide opportunities for upskilling and reskilling their employees through design education to ensure they remain competitive in a rapidly changing environment.

References

Abell, A. & DeVore, K. (2017). Embracing ambiguity: A framework for promoting iterative design thinking approaches in Engineering and design curricula, *American Society for Engineering Education*, 1-30.

Adelabu, O.S., Akinbogun, T.L., & Odewole, P.O. (2019). Design education in Nigeria: the place of the fourth industrial revolution, Proceeding, Visual Communication Design Conference held at Federal University of Technology, Akure, Nigeria on 15-16 August 2019, 565-582. ISBN 1119-5010.

Ally M. & Wark N. (2019). Learning for sustainable development in the fourth industrial revolution, Conference Proceedings & Working Papers, 2019 Pan-Commonwealth Forum 9 (PCF9), pp. 1–7. Scotland. http://hdl.handle.net/11599/3393

Ankrah, S. & AL-Tabbaa, O. (2015). Universities—industry collaboration: A systematic review, *Scandinavian Journal of Management*, 31, 387-408. http://dx.doi.org/10.1016/j.scaman.2015.02.003

Armstrong K., Parmelee, M., Santifort, S., Burley, J., Fleet, J.V., Koziol, M., Greenberg, R., Schwartz, J., & Tetrick, R. (2018). Preparing tomorrow's workforce for the Fourth Industrial Revolution for business: A framework for action, Deloitte Global Business Coalition for Education,
Available at: https://gbc-education.org/wp-content/uploads/sites/2/2022/03/Deloitte_Preparing-tomorrows-workforce-for-4IR-revised-08.11.pdf

Awan, U., Sroufe, R., & Kraslawski, A. (2019). Creativity enables sustainable development: Supplier engagement as a boundary condition for the positive effect on green

innovation, *Journal of Cleaner Production*, 226, 172-185. https://doi.org/10.1016/j.jclepro.2019.03.308

Baratta, D. (2017) The "T" shaped designer expertise. The "reverse-T" shaped designer horizon, *The Design Journal*, 20, sup1, S4784-S4786, DOI: 10.1080/14606925.2017.1352992

Bandura, A. (1991). Social cognitive theory of self-regulation, Organizational Behavior and *Human Decision Processes*, 50, 248-287.

Bosch, N., Härkki, T., & Seitamaa-Hakkarainen, P. (2022). Design empathy in students' participatory design processes, *Design and Technology Education: An International Journal*, 27(1), 29-48.

Braßler, M., & Block, M. (2017). Interdisciplinary teamwork on sustainable development—the Top ten strategies based on the experience of student-initiated projects. In W. Leal Filho et al. (eds.), Handbook of Theory and Practice of Sustainable Development in Higher Education, World Sustainability Series, Springer, pp. 65-77. DOI: 10.1007/978-3-319-47877-7_5.

Braßler, M. & Sprenger, S. (2021). Fostering sustainability knowledge, attitudes, and behaviours through a tutor-supported interdisciplinary course in education for sustainable development, *Sustainability*, 13, 3494. https://doi.org/10.3390/su13063494

Cezzar, J. (2020). Teaching the designer of now: A new basis for graphic and communication design education, *She Ji: The Journal of Design, Economics, and Innovation*, 6(2), 213–227. https://doi.org/10.1016/j.sheji.2020.05.002

Charles, S. (2022). Design thinking, a novel approach for an effective and improved educational system–A review, *International Journal of Professional Development, Learners and Learning*, 4(1), ep2205, 1–5. https://doi.org/10.30935/ijpdll/12010

Chiruguru, S. B. (2020). The Essential Skills of 21st Century Classroom, *ResearchGate*, 1-14. https://doi.org/10.13140/RG.2.2.36190.59201

Cohen, R.M. & Mule, L. (2019). Collaborative pedagogy in a design thinking education course, *InSight: A Journal of Scholarly Teaching*, 14, 29-42.

Costan, E., Gonzales, G., Gonzales, R., Enriquez, L., Costan, F., Suladay, D., Atibing, N.M., Aro, J.L., Evangelista, S.S., Maturan, F., Selerio (Jr.), E., and Ocampo, L. (2021). Education 4.0 in developing economies: A systematic literature review of implementation barriers and future research agenda, *Sustainability*, 13(22), 12763. https://doi.org/10.3390/su13221276

Conway, B., Leahy, K., & McMahon, M. (2021). Design education for sustainability: Identifying opportunities in Ireland's second level education system, Sustainability, 13, 8711. https://doi.org/10.3390/su13168711

Daskova Yu.V., Poliakova Ia.V., Vasilenko S.A., Goltseva O.S., Belyakova T.E., Shevalie K.N., & Vasilenko E.V. (2020). Development of creative independence of design students in course of higher education, *Propósitos y Representaciones*, 8(2) 1-12. Doi: http://dx.doi.org/10.20511/pyr2020.v8nSPE2.637

Dekoninck, E., Bridge, L. (2023). 'The T-shaped design engineer – using cohorts to explore how skills profiles differ through career stages', in Proceedings of the International Conference on Engineering Design (ICED23), Bordeaux, France, 24-28 July 2023, pp. 3533- 3542. DOI: 10.1017/pds.2023.354

Deepa, P. (2020). A study on the concepts of design thinking, International Journal of Engineering Applied Sciences and Technology, 4(12), 269–272.

d'Orville, H. (2019). The relationship between sustainability and creativity, *Cadmus Journal*, 4(1), 65–73.

Eckert, C.M., Maier, A.M., & McMahon, C. (2005). Communication in design. In J. Clarkson & C. Eckert (eds.) Design process improvement: A review of current practice, Springer-Verlag London, pp. 232-261. DOI: 10.1007/978-1-84628-061-0_10

Enechi, O. & Pattberg, P. (2020). Building strong partnership for SDGs: Analyzing participation of Nigerian stakeholders. In G. von Schnurbein (ed.), Transitioning to Strong Partnerships for the Sustainable Development Goals. Transitioning to Sustainability Series 17. Basel: MDPI, pp. 29-44. doi:10.3390/books978-3-03897-883-1

Falvey, L. (2018). Creativity and innovation for smart societies and sustainable development or smart R&D for increased sustainability? Conference Proceeding, Creativity and Innovation for Smart Societies and Sustainable Development, Phuket, Thailand.

Foster, M.K. (2019). Design thinking: A creative approach to problem solving, *Management Teaching Review*, 6(2), 123–140. https://doi.org/10.1177/2379298119871468

Garner, P., & Estry, D. (2017). A Primer on the T-professional. The Collegiate Employment Research Institute, Michigan State University. https://ceri.msu.edu/_assets/pdfs/t-shaped-pdfs/Primer-on-the-T-professional.pdf

Genç, R. (2017). The importance of communication in sustainability and sustainable strategies, *Procedia Manufacturing*, 8, 511–516. DOI: 10.1016/j.promfg.2017.02.065

Govindaraju, V. (2021). A review of social cognitive theory from the interpersonal communication perspective, *Multicultural Education*, 7(12), 488–492. DOI: 10.5281/zenodo.5802235

Hackett, E.J. (2020). Collaboration and sustainability: Making science useful, making useful science, *Sustainability*, 12(22), 9361. DOI: 10.3390/su12229361

Halkos, G. & Gkampoura, E.-C. (2021). Where do we stand on the 17 Sustainable Development Goals? An overview on progress, *Economic Analysis and Policy*, 70, 94-122. https://doi.org/10.1016/j.eap.2021.02.001

Higgins, L.E., & Smith, J.M. (2022). Documenting development of interdisciplinary collaboration among researchers by visualizing connections, *Research Evaluation*, 31(1), 159–172, https://doi.org/10.1093/reseval/rvab039

Ibeh, L.I., Ibeh, J.I., & Kaine, O.F. (2023). Promoting creativity and innovation thinking in tertiary institutions: A panacea for sustainable development, *Nigerian Journal of Management Sciences*, 24(2b), 335-339.

Kasza, J. (2019). Fourth industrial revolution (4IR): Digital disruption of cyber-physical systems, World Scientific News: An International Scientific Journal, 134(2), 118–147.

Kaur, K. (2021). Enhancing sustainable development through critical thinking in education: A multifaceted collaborative strategy, *International Journal of Research Publication and Reviews*, 2(11), 181–183.

Kaygan, P. & Demir, Ö. (2017). Learning about others: Developing an interdisciplinary approach in design education, Proceeding, Design Management Academy Conference: Research Perspectives on Creative Intersections, Hong Kong, pp. 1596-1611.

Keane, K. & Keane, M. (2019). Designing design education. https://bpb-us-w2.wpmucdn.com/voices.uchicago.edu/dist/a/1299/files/2019/07/sti2014_designing-design-education2.pdf

Khairil, M. et al. (2018). Communication strategy towards sustainable development goals (SDGs), *Journal of Food, Agriculture & Environment*, 16 (2), 191-193.

Kilicaslan, H., & Ziyrek, B.E. (2012). A research about creativity in design education, *Procedia – Social and Behavioral Sciences*, 46, 1461-1464. DOI: 10.1016/j.sbspro.2012.05.321

Kolb, A.Y., & Kolb, D.A. (2005). Learning styles and learning spaces: Enhancing experiential learning in higher education, Academy of Management Learning & Education, 4(2), 193–212.

Koutroubas, V., & Galanakis, M. (2022). Bandura's social learning theory and its importance in the organizational psychology context, *Psychology Research*, 12(6), 315-322. DOI: 10.17265/2159-5542/2022.06.001

Leicht, A., Heiss, J., & Byun, W.J. (2018). Issues and trends in education for sustainable development. UNESCO Publishing, pp. 7-16. https://doi.org/10.54675/YELO2332

López-León, R., & Valdez, G.G. (2018). Understanding empathy in design education, *International Journal of Educational Research and Innovation (IJERI)*, 10, 51-63.

Lor, R.R. (2017). Design thinking in education: A critical review of literature, Proceedings International Academic Conference on Social Sciences and Management (ACSSM) & Asian Conference on Education and Psychology (ACEP), Bangkok, Thailand, May 24-26, 2017, pp. 36-68.

Lyons, S.D., & Berge, Z.L. (2012). Social learning theory. In N.M. Seel (ed.), Encyclopedia of the Sciences of Learning, Springer Science+Business Media. DOI: 10.1007/978-1-4419-1428-6_1257

Mariani, L., Trivellato, B., Martini, M., & Marafioti, E. (2022). Achieving sustainable development goals through collaborative innovation: Evidence from four European initiatives*, Journal of Business Ethics*, 180, 1075–1095. https://doi.org/10.1007/s10551-022-05193-z

McCarthy, M. (2010). Experiential learning theory: From theory to practice, *Journal of Business & Economics Research*, 8(5), 131-140.

McDermott, L., Boradkar, P., & Zunjarwad, R. (2014). Interdisciplinarity in design education: Benefits and challenges. IDSA Education Symposium, Austin, 13 August, 2014.

Mhlanga, D., & Moloi, T. (2020). The stakeholder theory in the fourth industrial revolution, *International Journal of Economics and Finance Studies*, 12(2), 352-368. Doi: 10.34109/ijefs.202012207

Minott, D., Ferguson, T., & Minott, G. (2019). Critical thinking and sustainable development. In: Leal Filho, W. (eds) Encyclopedia of Sustainability in Higher Education. Springer, Chapter C, pp. 1–6. https://doi.org/10.1007/978-3-319-63951-2_529-1

Mróz, A., & Ocetkiewicz, I. (2021). Creativity for sustainability: How do Polish teachers develop students' creativity competence? Analysis of research results, *Sustainability*, 13(2), 571. https://doi.org/10.3390/su13020571

Nakao, B.H. & de Andrade-Guerra, J.B. (2019). Creativity, innovation, and sustainable development. In W. Leal Filho et al. (eds.), Decent Work and Economic Growth, Encyclopaedia of the UN Sustainable Development Goals, Springer Nature Switzerland AG, Chapter D, pp. 1-12. https://doi.org/10.1007/978-3-319-71058-7_55-1

Oueiss, E.A. & El-Khoury, J.R. (2023). Media strategies for promoting sustainable development goals, *Arab Media & Society*, 34, 1-20.

Petrova, M.N., de Steffen, M.D.C.C., Piumatti, R.G. & Lingán, C.R.L. (2022). Collaborative learning in international interdisciplinary teams, International Conference on Engineering and Product Design Education, 8–9 September 2022, London South Bank University, London, UK.

Rieckmann, M., Mindt. L., & Gardiner, S. (2017). Education for sustainable development goals: Learning objectives. The United Nations Educational, Scientific and Cultural Organizations (UNESCO).

Riel, A., Lelah, A., Mandil, G., Rio, M., Tichkiewitch, S., Zhang, F., & Zwolinski, P. (2015). An innovative approach to teaching sustainable design and management, Procedia *CIRP*, 36, 29 –34. doi: 10.1016/j.procir.2015.01.059

Rosen, Y., Stoeffler, K., & Simmering, V. (2020). Imagine: Design for creative thinking, learning, and assessment in schools, *J Intell.*, 8(2), 16. doi: 10.3390/jintelligence8020016

Ruminar, H., & Gayatri, P. (2018). Incorporate 4C's skills in EFL teaching and learning to face education challenges in the 4IR, Proceeding, The First International Conference On Teacher Training and Education 2018 (ICOTTE 2018). The University of Islam Malang (UNISMA).

Sandeep, K., Carlye, L. Christopher, M. Catherine, B., & Jessica, M. (2021). Novice designers' use of prototypes as communication tools, International Conference on Engineering Design (ICED21), 16-20 August 2021, Gothenburg, Sweden.

Sandri, O. J. (2013). Exploring the role and value of creativity in education for sustainability, *Environmental Education Research*, 19(6), 765–778. DOI:10.1080/13504622.2012.74997

Saviano, M., Polese, F., Caputo, F., & Walletzký, L. (2016). A T-shaped model for rethinking higher education programs, Proceeding, 19th Toulon-Verona International Conference, University of Huelva, Huelva (Spain), 5-6 September 2016, pp. 425-440.

Schleicher, A. (2018). The future of education and skills: education 2030. Available at: https://www.oecd.org/education/2030/E2030%20Position%20Paper%20(05.04.2018).pdf

Schwandt, T., Ofir, Z., D'Errico, S., El-Saddik, K. & Lucks, D. (2016). Realising the SDGs by reflecting on the way(s) we reason, plan and act: the importance of evaluative thinking, *IIED Briefing*, 1-4. http://pubs.iied.org/17380IIED

Shu, Y., Ho, S.-J., & Huang, T.-C. (2020). The development of a sustainability-oriented creativity, innovation, and entrepreneurship education framework: A perspective study, *Front. Psychol.*, 11, 1878. DOI: 10.3389/fpsyg.2020.01878

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines, *Journal of Business Research*, 104, 333–339. https://doi.org/10.1016/j.jbusres.2019.07.039

Starčič, A.I. & Lebeničnik, M. (2020). Investigation of university students' perceptions of their educators as role models and designers of digitalized curricula, Human Technology, 16(1), 55–91. DOI: https://doi.org/10.17011/ht/urn.202002242163

Stibbe, D., Reid, S., Gilbert, J., Raphael, L., Findlay, R., Albana Spiro, A., de Villiers, I., Wisheart, M., & Goransson, O. (2018). Maximising the impact of partnerships for the SDGs: A practical guide to partnership value creation, The Partnering Initiative and United Nations Department of Economic and Social Affairs (UN DESA).

Straková, Z. & Cimermanová, I. (2018). Critical thinking development—A necessary step in higher education transformation towards sustainability, *Sustainability*, 10(3366), 1-18. doi:10.3390/su10103366

Stuart, K. & Mataix, C. (2021). Preface. In D.F. Murphy & L. Stott (eds.) Partnerships for the sustainable development goals (SDGs), MDPI, pp. ix.

Sun, J.C. & Turner, H.A. (2022). The complementarity investment in university-industry collaboration, *Innovative Higher Education*, 48, 539–556. https://doi.org/10.1007/s10755-022-09641-6

Taimur, S. & Sattar, H. (2019). Education for sustainable development and critical thinking competency. In W.Leal Filho et al. (eds.), Quality Education, Encyclopedia of the UN

Sustainable Development Goals, Springer, Chapter E, pp. 1-12. https://doi.org/10.1007/978-3-319-69902-864-1

Tejedor, G., Sánchez-Carracedo, F., & Segalàs, J. (2022), *Sustainability*, 14(10530), 1-6. https://doi.org/10.3390/su141710530

Thornhill-Miller, B. (2023). Creativity, critical thinking, communication, and collaboration: assessment, certification, and promotion of 21st-century skills for the future of work and education, *Journal of Intelligence*, 11(54), 1-32. DOI: 10.3390/jintelligence11030054

Toronto, C.E. (2020). Overview of the integrative review. In C.E. Toronto & R. Remington (eds.), A Step-by-Step Guide to Conducting an Integrative Review. Springer Nature Switzerland AG, pp. 1–9. https://doi.org/10.1007/978-3-030-37504-1

United Nations (2015). Transforming our world: The 2023 agenda for sustainable development. https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf

Velásquez, H., Guerra, M.A., & Jiménez, M. (2023). WIP: Measuring interdisciplinary teams´ sustainable design with an SDG lens, Proceedings, Annual Conference and Exposition, American Society for Engineering Education, Baltimore Convention Center, MD, June 25-28, 2023. Paper ID #39333, pp. 1-19.

Wible, S. (2022). Empathy. In J.C.K. Tham (ed.) Keywords in design thinking: A lexical primer for technical communicators & designers, University Press of Colorado, Denver, Colorado 80202. https://doi.org/10.37514/TPC-B.2022.1725

Zande, R.V. (2011). Design education supports social responsibility and the economy, *Arts Education Policy Review*, 112, 26–34. DOI: 10.1080/10632913.2011.518123

Zervoudi, E.K. (2019). Fourth industrial revolution: Opportunities, challenges, and proposed policies. In A. Grau & Z. Wang (eds.), Industrial Robotics, IntechOpen. doi: 10.5772/intechopen.90412

Zhongbin, Z. (2023). Integrating arts education system enhancing students' level of creativity: A case study in Beijing, China, *International Journal of Academic Research in Progressive Education and Development*, 12(2), 2462–2472. DOI:10.6007/IJARPED/v12-i2/17639