education sciences

MDPI

Article

Embedding Sustainability in Learning and Teaching: Lessons Learned and Moving Forward—Approaches in STEM Higher Education Programmes

Kelum A. A. Gamage [1,*], Sakunthala Yatigammana Ekanayake [2] and Shyama C. P. Dehideniya [2]

[1] Centre for Educational Development and Innovation, James Watt School of Engineering, University of Glasgow, Glasgow G12 8QQ, UK
[2] Department of Education, University of Peradeniya, Peradeniya, Kandy 20400, Sri Lanka; sakuyatigammana@gmail.com (S.Y.E.); scpkdehideniya@gmail.com (S.C.P.D.)
* Correspondence: kelum.gamage@glasgow.ac.uk

Abstract: Embedding sustainability into pedagogical approaches is a key priority in higher education. Equipping students with knowledge, understanding, and skills, and developing the next generation of innovators and leaders, can potentially provide the change needed and create a real impact in the journey to a sustainable future. Advancement in Science, Technology, Engineering, and Mathematics (STEM), and corresponding industries can be seen as vital for the success of meeting a majority of the sustainable development goals, and hence the approaches taken to embed sustainability in learning and teaching in STEM higher education programmes can be considered significant in many ways. This paper is based on published literature over the last two decades and a semi-structured interview with 12 university academics from a developing country. Hence, the paper reviews approaches taken to embed sustainability in learning, teaching and assessments in STEM programmes. It also aims to investigate the actions taken by universities to integrate sustainability in STEM education and the remedies taken to minimise the impact of the pandemic on the effectiveness of the learning pedagogies used to integrate sustainability concepts.

Keywords: sustainability; learning and teaching; STEM education; higher education

Citation: Gamage, K.A.A.; Ekanayake, S.Y.; Dehideniya, S.C.P. Embedding Sustainability in Learning and Teaching: Lessons Learned and Moving Forward—Approaches in STEM Higher Education Programmes. *Educ. Sci.* **2022**, *12*, 225. https://doi.org/10.3390/educsci12030225

Academic Editor: James Albright

Received: 1 March 2022
Accepted: 13 March 2022
Published: 19 March 2022

1. Introduction

The coexistence and balance between humans and nature have been greatly challenged by the consequences of rapid economic growth triggered by scientific and technological innovations. As a result, the concept of sustainability, along with sustainable development and sustainable development goals, has evoked great concern from scientists, environmentalists, world leaders, and many others. According to the available literature, awareness of sustainability-related issues began in the 70s and continued being the focus of conference themes and academic papers, and the slogan of many development plans and projects and environmental-related activities, in the decades that followed.

As the motivations behind sustainability are complex and diverse, it has been defined from many perspectives. In the general sense, sustainability is the ability to maintain a certain level of balanced and stable development without disturbing the harmony between the natural world and the man-made physical world. Literally, sustainability means a capacity to maintain some entity, outcome, or process over time [1]. According to Stoddart et al. (2011) [2], sustainability is the efficient and equitable distribution of resources intra-generationally and inter-generationally with the operation of socio-economic activities within the confines of a finite ecosystem. Similarly, UNESCO (2012) [3] views sustainability as a paradigm for thinking about a future in which environmental, social, and economic considerations are balanced in the pursuit of development and improved quality of life. Accordingly, it is obvious that the term sustainability has always been focussed on

establishing a healthy relationship between social, economic, and environmental concepts, and issues of the present and future. They have also concentrated on transforming the global society, environment, and economy to the state of sustainability together.

Coupled with sustainability, the concept of sustainable development (SD) has also become a buzzword in development discourse, and is now associated with different definitions, meanings, and interpretations [4]. Among them, the most cited definition is the one proposed by the Brundtl and Commission report (1987): "Sustainable development is meeting the needs of the present without compromising the ability of future generations to meet their needs [5]". As a whole, SD aims at achieving social and cultural progress which, coupled with environmental equilibrium and economic growth, is a core concept within global development policy and agenda. The academic literature represents the aforementioned elements related to sustainability as the three-pillar conception of sustainability or the 'Triple Bottom Line': social, economic, and environmental.

In making the connections between sustainability and SD, sustainability is often thought of as a long-term goal while sustainable development refers to the many processes and pathways to achieve it [3]. Since education enables the young to fulfil their capabilities, it is a crucial investment for SD [6], and Education for Sustainable Development (ESD) extends its scope to deal with the complex amalgamation of issues relevant to environment, society, and economy [7] while paving the way for a more sustainable and just society for all. It encourages global changes in knowledge, skills, values, and attitudes while empowering and equipping current and future generations to meet their needs. Extending the landscape for SD further, the UN declared the period 2005–2014 as the United Nations Decade of Education for Sustainable Development (DESD) in 2002, emphasising the critical role of education in achieving sustainable development [7]. Taking the process of attaining global sustainability another step forward, the UN declared 17 Sustainable Development Goals (SDGs) in 2012 and education was given a crucial part because it is essential for progress on all goals [8]. Particularly, Goal 4 focused on quality education that ensures inclusive and equitable quality education and promotes lifelong learning opportunities for all; it linked to almost all the SDGs in one way or another.

Young generations as well as adults spend large periods of their life on education (formal, non-formal, and informal settings). The role of educational institutions, regardless of the academic level, is crucial in meeting sustainable development goals as they host basic skill development, and promote values, behaviours, and lifestyles favourable to a sustainable future and society while developing future professionals as change agents, and facilitating the creation of spaces where ideas are expressed freely, paradigms are challenged, creativity is promoted, and new knowledge is acquired and generated [9]. According to the UN (2007), "Academic institutions have the potential to generate a wave of positive change [10], and in achieving SDGs, higher education institutions have played a responsible role by implementing and driving sustainable development initiatives within their institutions". In this discussion of sustainable development, McGunagle and Zizka [11] noted that Science, Technology, Engineering, and Mathematics (STEM) higher education programmes currently offer theoretical knowledge and industry-related competencies that seek to prepare graduates to become leaders capable of meeting 21st-century demands. Pahnke et al. [8] also built up the connection between STEM and sustainability, and said that STEM disciplines are called upon to participate in the social process of searching, learning, and shaping solutions to global sustainability issues.

Supporting the same point, Dotson et al. [12] suggested that access to quality education in STEM is linked to reduced poverty, higher economic growth, and more resilient democracies; these disciplines play an essential role in addressing many of the SDGs.

Scholars, practitioners, and policymakers are counting on STEM education to lead towards global sustainability. In that process, higher educational institutions (HEI) have been recognised as centres of knowledge generation and skill development. They are also expected to make a concerted effort towards shifting the focus from mere learning to learning sustainably, which is known as lifelong learning. Moreover, HEIs play a significant

role in inculcating in students the "values and skills that contribute to social progress and the advancement of knowledge" [10]. Hence, universities require innovative sustainability pedagogical methods for preparing students to create a more sustainable world through rigorous analysis and innovative solutions [13]. Traditional methods of lecture and assessment over-simplify complex issues and trade-offs into right or wrong answers; asking students to regenerate pre-packaged information presented by their teachers [14] and emphasising an individual's knowledge-based achievements will not produce positive results in terms of sustainability. Moreover, many research studies have shown that didactic, teacher-centred education results in reduced cognitive, behavioural, and socio-emotional outcomes. Therefore, educating for sustainability requires that students develop the skills to be change agents who grapple with real-world challenges through explorations that engage multiple ways of knowing and move beyond facts as the central form of knowledge [14]. With respect to higher education and STEM education, a critical pedagogy including problem- or project-based learning, cooperative or collaborative learning, experimental learning, inquiry-based learning, case studies, and research-based learning, have been suggested as the most appropriate approaches by scholars. Hence, this article focuses on finding answers for the following research questions:

1. What is the role of STEM higher education in sustainability?
2. What kind of pedagogical strategies are used in STEM higher education to promote sustainability?
3. How do university academics perceive the sustainability concept in education?
4. What approaches are used usually to promote sustainability through teaching, especially during the pandemic?

Further, by answering the above questions, it aims to achieve the following objectives in relation to sustainability, higher education, STEM education, and learning pedagogies:

- Review approaches taken to embed sustainability in learning, teaching, and assessments in STEM programmes.
- Identify university academics' views on promoting sustainability concept through higher education.
- Investigate actions taken by universities to minimise the impact of the pandemic on the effectiveness of learning pedagogies used to integrate sustainability in STEM education.

The background literature mainly focuses on the most applicable academic research outcomes for the main topic of study under areas of STEM higher education. It discusses the academic literary evidence for the role of STEM education in sustainability, and what are the most significant STEM educational pedagogies promoting sustainability.

2. Role of STEM in Sustainability

In general, STEM education refers to the teaching and learning method that integrates the content and skills of science, technology, engineering, and mathematics while providing students with opportunities to become problem solvers, innovators, inventors, logical thinkers, and tech literates. Alternatively, students get a chance to apply knowledge within meaningful real-life related contexts because it supports independent thinking and responsible action. It also reinforces engagement with technological and societal changes while enabling students to become responsible individuals who adopt sustainable development in their locality and, by extension, the global context.

STEM education is the integration of four disciplines with two possibilities: input and output in education [15]. The passage of content knowledge and development of skills in those disciplines function as the input. Conversely, STEM is also connected to economic competitiveness in the global market, and is required to fill output requests such as guaranteeing and maintaining energy and productivity needs [16]. Furthermore, STEM has been identified for its potential to contribute to positive social change through sustainability, considering that sustainability issues are inherently interdisciplinary.

Smith and Watson [17] used the Australian context to agree with the common perception that, for future prosperity, a substantial proportion of the global workforce needs to be educated in STEM disciplines. Further, investing in STEM education is key to productivity growth and higher living standards for our community, and it has been identified as the driving force for economic growth. Accordingly, applicability of STEM is the way forward for elevating sustainability in the universal perception. Hamilton and Thomas [18] also recognised that sustainability and sustainability science are increasingly becoming an accepted part of the general lexicon of STEM disciplines. Confirming it further, Zizka [19] said that STEM-related subjects are integral to sustainable development and for solving global sustainability issues in a meaningful and knowledge-based way.

In contrast to many favourable views on the relationship between STEM and sustainability, Davis [20] argues that STEM's contribution to sustainable development is limited. According to this argument, integrated and holistic approaches, rather than narrow STEM approaches, offer the best opportunities for successful and widespread ESD. It emphasises the need for rethinking STEM education as sustainability is fundamentally a human problem, not a science-and-technology problem. Further, the author supports the argument with Holbrook's (2009) suggestion: "Education for SD has little to do with accumulating a body of scientific knowledge, and is far more aligned with the development of personal and social aptitudes leading to responsible citizenship (p. 44)".

However, a sustainable future depends on a workforce of professionals knowledgeable about creating practices, processes, and infrastructure to optimise resource management, and a community informed about the ethics and influence of human activity on the integrated environmental, economic, and social aspects of sustainability [21]. As proven by the academic literature, systematic STEM education is capable of producing individuals to fulfill workforce requirements, which ultimately contributes to sustainable development both locally and globally.

2.1. University Sector

It is a known fact that higher education institutions (HEIs) play a key role in fostering social transformations that are critical for facilitating the transition to a sustainable future. Shepherd [22] defines higher education for sustainable development as "an approach to education aimed at responding to societal expectations to address environmental, social, cultural and economic issues that threaten sustainability of life on Earth". Similarly, Leifler and Dahlin [23] also confirm that higher education is instrumental in fostering the skills needed for graduates to become change agents for sustainable development. As recognised by scholars and policymakers, to best achieve the aims of the global sustainability agenda through education, there needs to be changes in educational policies, curriculum, and practices regardless of the academic level. Franco [24] highlights this in several studies and confirms the importance of a major transformation in higher education that needs to occur across all disciplines and levels of study.

Transversely, STEM higher education has been perceived as the key to propelling a nation from (1) developing to developed, (2) a middle-income country to a high-income country, and (3) one with a semi-skilled workforce to that with a highly skilled workforce [25]. In that case, as Zizka [19] suggests, for addressing sustainability in STEM education, HEIs must change the way students are taught to promote and provoke a more sustainable mindset. HE institutions need to teach sustainability, live it, and believe in it. Admittedly, lasting culture change requires commitment from the top. In line with expected advancements in the 21st century, there is global awareness for a shift in HE for sustainable development. That has been intensified with the start of the UNESCO Decade of Education for Sustainable Development (2005–2014), and universities have taken several approaches to rethink and amend their academic activities leading to sustainability. Weiss et al. [26] also noted the efforts of the UN to advance the implementation of ESD in HEIs in accordance with the strong impetus, support, and policy frameworks that have

been put forth by the UN decade for ESD (2005–2014) as well as the subsequent (2015–2019) Global Action Programme (GPA) and, most recently, the SDGs.

2.2. Industrial Sector

Financial instability and economic inequity, threats to food safety and increased health risks, climate change, biodiversity loss, decline in consumable water resources, and depletion of fossil fuels and energy sources are some of the interrelated issues that the world is facing today. Dotson et al. [12] supposed that access to quality education in STEM is linked to reduced poverty, economic growth, and more resilient democracies. In support of that, as mentioned in the literature, STEM competencies greatly impact each person's ability to contribute to economic success nationally and globally. As indicated through many research studies, STEM graduates come with strong soft skills (enterprise skills) and are much more employable [11]. Additionally, STEM has been recognised as the biggest asset to driving innovation and creativity. Moreover, a technology-and knowledge-driven economy needs workers trained in science, technology, engineering, and mathematics [27]. Hence it is long believed that STEM disciplines play an essential role in addressing many of the global issues related to the industrial sector.

Rapid technological advancement is a major driver of economic growth today, and the reason for improved living standards across the globe. Digital technologies radically transform the structure of every organisation reshaping the roles of professions. This has immensely influenced the field of education, including teaching and learning. There are indications of a fourth industrial revolution that is to come hand in hand with the development of digital technologies. Consequently, the future requires workers to think creatively, work collaboratively, deepen their emotional IQ, and integrate technology into everything they do [27]. STEM education has the potential to produce a workforce with a global mindset, critical thinking, problem-solving, and collaboration skill, which are highly required for sustainable development and central to innovation and a productive, adaptable workforce.

To prepare students for this technology-driven sustainability, the education system, especially higher education, should focus on developing skills required for sustainable development. Hence, HEFCE (2009) [28] states that the "greatest contribution HE can make to sustainable development is enable students to acquire the skills and knowledge that allow them to make a lasting difference". HEFCE (2009:21) further suggests that in order to do this, the higher education sector must develop curricula and pedagogy that provide students with the required skills.

2.3. Curricular Changes and Integration of Sustainability

Over the last 20 years, scholars, activists, and others have noted that through the research they conduct, the engagement they experience with the broader community, and the operations they oversee, colleges and universities can serve as test sites and models for sustainable practices and societies [29]. Therefore, in the journey to sustainability, education should not restrict itself to just giving students information, but also provide them with an experience that brings opportunities to work collaboratively, appreciate multiple perspectives, be reflective, think critically and creatively, and act constructively [30]. According to AASHE [29], the existing curriculum in higher education has not been developed to examine how we can shape a sustainable world. Much of the curriculum has been developed to provide students with an increasingly narrow understanding of disciplines, professions, and jobs, and is focused on specific knowledge and skills employed in a given area. Consequently, to promote the change needed in society, HEIs themselves will need to change even quicker than society as a whole through attitudes enabling the integration of sustainability, regulations, standards, and faculty goals [23]. Alternatively, sustainability issues are complex, and vary locally and globally at different degrees. To ensure a more sustainable future, higher education will have to provide college and university graduates with the skills, background, knowledge, and mental habits that prepare them to meet

challenges in the future [29]. As a result, education for sustainability has become part of mainstream higher education policy in many countries. It encompasses various aspects, including knowledge of environmental, economic, and other social issues of sustainability; nurturing of ethos and values; and the adoption of participatory teaching and learning methods. Significantly, in the UK, progress has been largely confined to curriculum content changes [31,32] relating to cognition and knowledge. Its authorities have failed to deliver on other ideas, understandings, values, behaviours, and skills that are widely recognised as important to prepare graduates for future challenges. Hence, the need for more profound learning experiences that can equip graduates to make "informed decisions in their home, community and working lives" is being stressed upon. It is obvious that HE providers need to identify appropriate content and forms of teaching–learning to achieve sustainability-focussed learning outcomes along with proper assessment that can enhance sustainability skills and literacy in graduates.

An interdisciplinary, holistic, values-driven, and locally relevant curriculum integrated with sustainability concepts is highly recommended in higher education. Integrating sustainability into college and university curricula is challenging, but studies have shown a variety of attempts in this regard. According to the report "Embedding Sustainable Development in the Curriculum", sustainability concepts have been fully integrated into some university courses. In the process of integrating ESD in HEIs, Weiss [26] identified two levels: micro and macro. At the micro level, integration is performed through teaching and learning in courses, while at the macro level, it is carried out through programmes and curricula.

Curriculum change processes are complex and vary remarkably, from institute to institute, programme to programme, sometimes even from discipline to discipline. They may even change in terms of their breadth, depth, and influences [26]. In addition to that, cluster analysis results of the study have revealed two distinct implementation phases: ESD can be implemented from the bottom-up, from the top-down, or both, and the impetus can stem from manifold external or internal stakeholders. Other than that, six distinct implementation patterns—(1) collaborative paradigm change, (2) bottom-up, evolving institutional change, (3) top-down, mandated institutional change, (4) externally driven initiatives, (5) isolated initiatives, and (6) limited institutional change—have also examined in the same study.

Leifler and Dahlin [23] specifically focussed on the views of Mulder (2017) regarding the integration of sustainability in engineering curricula, and as they have stated, generally the integration process follows one of two approaches, namely:

(1) Focussing on analytical approaches of the impacts of technology such as life-cycle assessments of products.
(2) Trying to achieve a positive system transformation through management and innovation related to technology and social change.

Taylor [21] specifically focussed on the possibility of integrating mathematics with sustainability. According to Taylor, sustainability can be addressed at all levels of the mathematics curriculum. Quantitative reasoning skills (logic, mathematics, and statistics) are also at the core of understanding and interpreting many sustainability concepts, and are required for making sustainability-related decisions. Further, it is essential in so many academic disciplines—not just the sciences, engineering, and economics, but also in history, linguistics, art, and media studies. Therefore, there are ample opportunities for introducing sustainability examples in math courses, from algebra and geometry to calculus and statistics, and even in advanced graduate-level courses. And the writer confirms the argument further by saying that quantitative reasoning in mathematics and sustainability have emerged as two similar, important, and mutually supportive themes that are critical for the individuals' personal, professional, and public lives [21].

Parallel to that, Susilwati [33] established the relationship between science and sustainability. It was stressed that education leading to the sustainability of resources and the environment certainly needs to be integrated into science subjects. According to the views

of science, it reflects a holistic problem in real life. Natural science can be studied from several angles, namely as a body of knowledge, a way of thinking, a way of investigation, and its relation to technology and society.

Hamilton and Thomas [18] also propose a concise set of five learning objectives for sustainability education that can be included in almost any course while not sacrificing appropriate content.

- Teach in context: Include sustainability-oriented content and introduce "global realities".
- Include real-life place-based examples.
- Emphasise "designing the future". Teach the tools of complexity, systems thinking, and design thinking.
- Explicitly recognise the ethical and affective (moods, feelings, attitudes, etc.) aspects of the issues raised.
- Teach specific skills that empower students to become catalysts and leaders of change.

As they said, integrating sustainability education is possible if it can be incorporated into what is already being taught. However, there is no universal consensus on what specific sustainability-related competencies should be included in a curriculum or how is it to be performed, or when and where. To well establish sustainable education in the curriculum, it would require a remarkable modification in the way subjects are taught and learnt. To that end, more flexible pedagogical approaches combined with practical and applied learning opportunities are essential.

3. Learning Pedagogies in Embedding Sustainability in STEM

Broadly, pedagogy is referred to the whole learning process, which includes the learning environment, the learning community or the teacher and the students, and the assessment or reflection on the teaching–learning process. Westbrook et al. [34] viewed pedagogy itself as a contested term. According to Bernstein's [35] definition, pedagogy is "a sustained process whereby somebody(s) acquires new forms or develops existing forms of conduct, knowledge, practice, and criteria from somebody(s) or something deemed to be an appropriate provider and evaluator". In particular, it can be defined as the relationship between theories and practices used for educating somebody regardless of the academic level. Hence, for both school and university education, novel and innovative pedagogical methods are required to enable students to participate successfully in the sustainability process.

Sustainability issues affect personal, professional and social life. To build competence in sustainability and promote sustainable change, Redman [14] acknowledged the importance of integrating three critically significant elements: educational pedagogy, behavioural change, and sustainability competencies. Hence, pedagogical approaches are given a pivotal place in sustainability-focused education. This has resulted in a variety of creative and critical pedagogies. Redman [14] focused on a study performed on the effect of pedagogical approaches on sustainability courses, and found that multi-methodological, experiential, and active learning approaches improved students' system thinking skills and provided a cognitive understanding of sustainability. Redman [14] advocates three interconnected pedagogical methods—real-world learning, critical problem-solving, and experiential learning—considering their significance to cognitive understanding and skill-building for sustainability. Moreover, Leifler and Dahlin [23] make references to several studies, stating that in both research and teaching, successful sustainability initiatives are characterised by strong inter-disciplinary activities, even ones transgressing disciplinary boundaries to reach solutions out of reach of any one discipline. Continuing the conversation on pedagogy for sustainable education, Sprain and Timpson [13] refer to several studies and state: "We realise that there are other approaches to teaching sustainability, including interdisciplinary student projects, field experiences, team-teaching with scholars from different disciplines, and games". Hence, to build up a positive vision of the sustainable world that aims to create together, it is crucial to promote creativity, the ability to come up with innovative

solutions, responsibility, respect for the work at hand and other participants, and many other competencies through education. Teaching–learning processes containing creative and critical pedagogies can be assumed as the vehicles to reach the expected destinations. Specifically, teaching and learning methods for implementing STEM education as part of an interdisciplinary curriculum vary widely. They include project-based learning, problem-based learning, inquiry-based learning, and technology-based learning, each of which can be used differently depending on the classroom situation [36]. The pedagogies used and cited in empirical research studies related to STEM higher education and sustainability are discussed below.

Case studies have been identified as a productive pedagogical approach to teaching for and about sustainability by scholars. Sprain and Timpso [13] suggest that this pedagogical tool has interdisciplinary and even trans-disciplinary applications, and appears well suited to imply sustainability-directed STEM higher education. Furthermore, as a part of sustainability pedagogy, the case study approach can be used across disciplines (ecology, sociology, education, agricultural sciences, business, communication, etc.) at multiple levels, including in courses that are not explicitly about sustainability, environmental concerns, or even science. Schoolman et al. [37] also confirmed the appropriateness of the case study approach and said that they can be used in cross-listed or interdisciplinary courses that focus on the intersection of multiple disciplines, including courses on sustainability science, which is often envisioned as an interdisciplinary field.

Apart from that, Sprain and Timpson [13] highlight Seager et al.'s (2011) argument that case-based approaches are particularly well suited to teaching about sustainability and building capacity to address the challenge of tackling wicked sustainability problems. Further, it is acceptable that case studies can be used to build the capacities (systems thinking, anticipatory, normative, strategic, and interpersonal competencies) necessary to address problems of sustainability even in classes not explicitly focused on sustainability. More broadly, case-based approaches can be used as an educational tool to help students explore contemporary sustainability challenges.

3.1. Inquiry-Based, Problem-Based, and Project-Based Learning

Within the concept of STEM Education, inquiry, project and problem-based learning are used to scientifically inquire about natural phenomena or problems or to introduce new concepts to the student during the teaching–learning process. Most specifically, these approaches address children's inquisitiveness and thirst for exploration, their desire to get to the bottom of things and ask questions, while encouraging them to find answers for current issues with understanding. Common inquiry/problem/project-based STEM Education is built on constructivist theories of learning, and has long been applied in STEM, giving opportunities to explore 'hands on', experiment, ask questions, and develop responses based on reasoning. In addition to solving problems, students build a proper understanding of the phenomena of the natural world ('minds on') through in-depth study issues just as scientists do.

Martín-Garin et al. [38] recognised problem-based learning (PBL) as the most highly developed methodology in the university environment, where students work independently to explore a problem. In addition, Redman [14] says that problem-based learning centres on a complex problem that does not have a single correct solution. The critical thinking and problem-solving process should be student-led, experiential, and collaborative in order to emphasise that there is more than one correct point of view when exploring problems. The ultimate objective in PBL is not to solve the problem but to discuss how to solve the problem [38]. Considering the advantages of PBL, scholars have focussed on these approaches as effective teaching approaches to address the student community.

3.2. Real-World Learning

Redman [14] emphasised the applicability of real-world learning in the pedagogy for sustainability and mentioned, referring to several empirical studies, that "real-world explo-

rations incorporate authentic investigations with complex goals and provide opportunities for problem-solving while involving students' beliefs and values". In contrast, Brundiers et al. [39] highlighted real-world learning opportunities that help students increase their understanding of sustainability problems (knowledge), and complement their methodological competence in applying problem-solving approaches (strategic competence cluster). They also allow students to gain hands-on experience in how to link knowledge to action for sustainability (practical competence cluster). Students learn to develop sustainability strategies and programmes in the actual context of existing processes, politics, or tradition. Moreover, real-world learning opportunities allow students to recognise and engage in different forms of collaboration at different degrees of intensity (collaborative competence cluster). Similarly, by providing assignments that focus on solving real sustainability issues, educators can engage students and help institutions turn towards more sustainable behavioural and policy norms. It also enables students to apply theory to practice, and builds interpersonal skills for engagement with stakeholders, both of which are critical for sustainability (Redman, 2019).

On the ground of all above, Brundiers et al. [39] suggested that through real-world learning experiences, students can apply their classroom learning to study the sustainability issue and engage with people in the community. Four methods for providing real-world learning experiences to students are: (1) bringing the real world into classrooms, (2) visiting the real world, (3) simulating the real world, and (4) engaging with the real world. Project- and problem-based learning, service learning, and internships expose students to corresponding real-world settings in communities, businesses, and governments, and have a common focus on real-world problems. Brundiers et al. [39] suggested these as effective in providing sustainability education since they seem to be a suitable way for students to develop key competencies in sustainability.

In addition to the above-mentioned approaches, Dotson et al. [12] termed co-learning framework and peer-led learning as two ways that ignite the aim to improve sustainability and scalability of STEM coursework in communities where this type of education is absent. Co-learning, also known as critical pedagogy, or experimental, cooperative, and/or collaborative learning, is a form of active, dynamic learning where students and teachers create a collaborative learning environment, in contrast with traditional passive teaching formats. Improved critical thinking, enhanced communication skills, improved socio-cultural awareness for both teachers and students, and a significant boost in student performance have been identified as the benefits of this approach.

In addition, Petrun Sayers et al. [40] prioritised cognitive maps as a STEM-based sustainability education evaluation tool. Importantly, cognitive mapping plays an interesting role in the field of sustainability because the tool can effectively capture the field's interdisciplinary nature. It has also proven to be a tool for building and examining understanding of additional STEM and sustainability concepts. Mathematical modelling has also been tested as an effective pedagogical strategy in STEM projects to enrich students' competencies regarding sustainability in higher education [36]. Mathematical modelling describes a set of comprehensive processes used to transform real-life problem situations into mathematical models, draw mathematical conclusions, and then apply those conclusions back to the real world.

Dawe et al. [41] categorised pedagogical applications commonly used for teaching sustainability in Embedding ESD into Higher Education: Final Report for the Higher Education Academy, teaching methods employed in the delivery of sustainability.

- Conventional methods: lectures, seminars and tutorials
- The personal: role models
- Re-connecting to reality: real-life and real-time interpretation, field trips, environmental audits, the use of role-playing, a year abroad; and development of case-studies
- Holistic thinking

As a whole, the above discussed pedagogical approaches appear to be student-centred and capable of offering a holistic education catering to the needs of education for sustainable development.

4. Materials and Methods

This research article has followed a qualitative approach that is mainly based on two types of data, taken from systematic document analysis and interviews with university academics. Literature for the analysis of the documents was exclusively retrieved from online databases. Predetermined selection criteria were applied during the database search in order to keep the number of articles reasonable, and to ensure the quality of the sources. The search was restricted to peer-reviewed journal articles, conference papers, and reports in full text. There were no restrictions on the year of publication or the geographical regions considered, and the selection of documents followed text titles, abstracts, and whole texts that appeared in databases of Google Scholar, J-store, Tandfonline, Elsevier, and recognised institutional websites (e.g., UNESCO).

In the selection process, both empirical and theoretical studies were included regardless of the research method followed. The comprehensive search resources were completed based on a wide range of key terms and phrases, including "Sustainability and Education for Sustainable development, STEM higher education, Learning pedagogies for sustainability learning, and STEM-related learning pedagogies". Similar terms that are often used interchangeably in the literature were also used. As the search action resulted in a limited number of appropriate and accessible sources, the reference section of the recovered texts were studied for more relevant texts. As a whole, the original samples came up to 235 documents and their abstracts, and the contents were examined in detail. This led to the removal of duplicates and articles with directly unrelated content, and the original samples were reduced to 57 articles. Finally, the content of the selected resources was studied and analysed.

As the other source of data, discussions with 12 select university academics from the Science, Engineering, Mathematics, Agriculture, Information and Communication fields were conducted. In the selection, their preferences to participate in the discussion were considered. The interview was a semi-structured interview, and the interviewer used a set of predetermined questions related to the cause of the study. The respondents were allowed to express their views on the implementation of education for sustainable development, pedagogical approaches, and how current educational practices focussing on education for sustainability have been impacted by the pandemic situation. Interview transcripts were made, and responses were analysed narratively and reported according to the question order in the interview schedule. Then the required data were organised into two main sections to answer the research questions.

5. Results and Discussion

The following section focusses on examining learning pedagogies practised in the process of embedding sustainability in STEM, as reported in the research literature. Further, it prominently answers the second research question. The third and fourth questions are answered through interview data, i.e., the experiences of university academics in delivering sustainability concepts during the teaching–learning process.

5.1. Analysis of Learning Pedagogies in Embedding Sustainability in STEM

STEM instructions transform the conventional teacher-centred teaching–learning into active student-centred learning with the use of the following pedagogical instructions: inquiry, PBL, case studies, argumentation and reasoning, digital learning, computer programming and robotics, and cooperative learning, among others. Many of the research study results have validated the effectiveness of pedagogical strategies in STEM education promoting ESD [36].

There has been widespread discussion on innovative sustainability pedagogies. For example, studies by Küçüksayraç and Kırca [42] and Hansen et al. [43] have confirmed that sustainability is closely connected with contextualised problem-based STEM projects and, as such, is best to integrate sustainability concepts into the STEM teaching–learning process. Furthermore, Martín-Garin et al. [38] reported the pedagogical approaches developed and applied by a multidisciplinary team in the Civil Engineering and Technical Architecture degree programme during the academic years 2013–2014, in a university from Spain. According to that PBL or RBL (research-based learning), life cycle assessment (LCA) and computational thinking (CT) approaches have been used with an aim to acquire a sustainable approach to work "soft skills" competencies into sustainability. As it reported, implementing PBL resulted in higher achievements in exams of physical and mechanical properties (Engineering), together with improvements in teamwork and collaboration as well as increased awareness of climate change. As a whole, they all stress the importance of acquiring sustainability skills through study modules as part of students' professional qualification profiles.

Moreover, Dobson and Tomkinson [44] stated that using inter-disciplinary problem-based approaches to embedding SD in the curriculum is not only practicable but also desirable. However, the approach to the design of problem scenarios has to be adjusted to the nature of the "wickedness" of sustainability issues, and be appropriate to the student cohort and institution.

The study of Suh and Han [36], which used mathematical modelling to bridge STEM education with ESD, revealed that it is effective in inducing positive change in students' perceptions about the use of STEM for predicting future societies and sustainable development, and making responsible decisions that promote harmony among the environmental, economic, and social domains. Further, Peter and Reid [45] argued that broader and more holistic conceptions of mathematics allow room for integration with the broader conceptions of sustainability, and mathematical modelling facilitates that requirement. Cognitive mapping is a proven, useful tool for building and examining an understanding of additional STEM and sustainability concepts. Cognitive mapping can assist instructors in tracking student progress with sustainability concepts and test the effectiveness of curricular interventions. The method suggests how students conceptualise and organise knowledge in an open-end format, offering an alternative to multiple-choice or sheer memorisation techniques, and moving towards a method that allows students to integrate diverse higher-order constructs to develop metaphorical thinking [40].

Case-based teaching has long been used as an effective pedagogical practice in many disciplines. Hardin et al. [46] and Wei et al. [47] referred to the Michigan Sustainability Case (MSC) initiative as an innovative attempt to equip the next generation of scientists and professionals with the competencies necessary to understand, analyse, and solve wicked sustainability challenges. Similarly, Davis [48] also highlights the importance of introducing and effectively integrating case studies on sustainable development into traditional engineering disciplines. Based on his study, he concluded that case studies allow students to visualise how sustainable development can be applied to all engineering decisions, and also give them the capacity to understand the social, environmental, and economic considerations associated with all projects, as well as in the application of their knowledge and skills to make informed engineering decisions. Standing on the findings of a study to design a MetaMAP (an interactive graphic tool for collaborating to understand social-ecological systems and design well-integrated solutions), Maher et al. [49] discussed the benefits of case study-design approach to achieve sustainable development goals.

Wei et al. [47] analysed the outcomes of a case study based on environmental education and said that with regard to case studies, some evidence exists that their use promotes knowledge gains, critical thinking, and problem-solving skills. Additional evidence indicates that teaching through cases and examples that provide "real-world" relevance (i.e., "socio-scientific issues") increases students' interest and engagement in learning, and

promotes the development of higher-order thinking. The case study method fits the lessons for teaching sustainability and addressing problems inherent in sustainable development.

Sadowski et al. [50] discussed the effect of the "game-theoretic, experiential pedagogy", which moves the learning experience from passive to active, apathetic to emotionally invested, narratively closed to experimentally open, and predictable to surprising. Basically, it focusses on ethical skill development in science and engineering students, and researchers have seen positive results in relation to the content knowledge and sustainability ethics of students.

Most higher education institutions tend to integrate e-learning within their pedagogical provisions, and it has become crucial as a result of the pandemic. It focusses on enhancing teaching–learning, student assessment, and improving students' satisfaction and outcome. Even before the pandemic situation, e-learning had gained considerable attention. Altomonte et al. [51] aimed to explore the opportunities offered by interactive and situated learning (e-learning and m-learning) in support of education for sustainability in disciplines of the built environment. The findings have added empirical evidence to the view that information and communication technology-enhanced pedagogies can substantially contribute to the agenda of sustainability in higher education, primarily due to their affordance of interactive communication and contextualisation of knowledge, while guaranteeing flexible time and pace of learning.

As a whole, it is evident that PBL and case studies have been identified as the leading pedagogical approaches to developing sustainability skills. Game-based learning approaches and cognitive mapping are similarly recognised as influential. There is increased popularity for e-learning due to the pandemic situation too. Hence, the following sub-topic will concentrate on discussing the experiences of academics in a developing country, revealing the current practices related to that context.

5.2. Views of University Academics of a Developing Country

5.2.1. General Views on "Sustainability" Concepts as University Academics

The university academics who participated in the study generally view sustainability as a very important and essential concept for everyone everywhere, especially in the future, due to the scarcity of resources. They also perceive sustainability as a broad and progressive concept that is relevant, and can be applied at any level (e.g., national, regional, organisational, and personal). They recommend that sustainability be adopted in every possible field since it is one of the major areas that need to be focussed on for ensuring the continued existence of the world. Hence, considering its ability to uphold the individual, the community, and the whole world, sustainability must be implemented rather than used as an object of mere rhetoric.

Sustainability is required to create a conducive living environment while maintaining the good of all and carrying out daily activities. It is the process of meeting one's own needs without compromising the ability of future generations to meet their needs. Sustainability is a solution/approach/practice that performs well in the social, economic and environmental dimensions. It is a concept aimed at ensuring that things exist without interrupting other systems around them, and humans grow, develop, and gain resources without compromising the ability of future generations to do the same.

In response to the question "What are your general views on sustainability?", some highlighted the relationship between education and sustainability. According to them, "Education, research, and innovation are essential for sustainable development. University researchers, teachers, and students work in partnership with citizens and the private and the public sector, co-creating knowledge that can produce solutions". Another point that emerged from the responses was the concept of a sustainable university. "A sustainable university is an educational institution that educates global citizens on sustainable development, offers relevant insights on urgent societal challenges, reduces the environmental and social footprints of its campus operations, empowers students and staff to act, and makes sustainability a central priority", they said. They also highlighted the importance of

university education, and proposed that university education graph all modern techniques and latest updates (knowledge) that need to be transferred to students. To support that, university curriculum should provide more opportunities for students to become familiar with sustainability concepts. University academics hold a similar perception on sustainability to that defined in the academic literature. Additionally, they agree that sustainability is becoming more and more important in all aspects of life, and university academics are responsible for making a key contribution to achieving the goals.

5.2.2. Views on Education for Sustainable Development

Education on sustainable development has been perceived as a necessity and timely topic that should be addressed at every level of education, whether school, university, or other educational settings. Especially for higher education institutions, it is a very important topic aligned with the objective of achieving the UN's SDGs. Henceforth, all forms of education should have subject components on overall sustainability as well as those specific to the study area/field of speciality. In the same way, ESD has been suggested as mandatory for education, and should be associated with all disciplines.

ESD has been identified as "a process that promotes the development of knowledge, skills, understanding, values, and the actions required for creating a sustainable world that ensures environmental protection and conservation, promotes social equity, and encourages economic sustainability". A similar explanation also emerged from the discussion: "Education on sustainable development empowers learners with knowledge, skills, values, and the attitude to make informed decisions and take responsible actions for environmental integrity, economic viability, and a just society". It is in contrast with the idea of those who see ESD as a concept that thinks only about environmental protection. ESD has been recognised as highly needed for every student and academic today and in the future. There is emphasis on the need for awareness after university study.

5.2.3. Consideration Is Given for "Education for Sustainable Development" within the Academic Activities and Pedagogies in Practice

According to the responses of the academics, a majority consider education for sustainable development as essential, and they provide space for it in their teaching. However, some were not sure about making room for ESD experiences, and provided "maybe" as the answer. Remarkably, one even answered with a "no", contending that within the teaching and learning process there is no chance for the concept of ESD. This indicates the unawareness of the importance of ESD initiatives among academics, and further, portrays their uncertainty and lack of readiness in incorporating sustainability criteria into their professional practices. Moreover, it sheds a critical light on the consequences that may be expected in the future due to the lack of preparedness of university teachers for change.

On integrating sustainability concepts in university courses, it was revealed that much consideration was given to the subject particularly in engineering. Three academics came out with their personal involvement in integrating sustainability.

- Academic 1: "I introduced a technical elective on Sustainable Manufacturing in 2013, and it has now become a core course in the Manufacturing and Industrial Engineering Bachelors' programme".
- Academic 2: "I teach the following concepts related to sustainability: resource and energy sustainability, environmental sustainability, product life cycle sustainability, sustainable consumption and production".
- Academic 3: "I have given prominence to integrating USDGs in all my teaching and research activities for several years now".

The above statements reflect that academics involve themselves in sustainability initiatives and sometimes work in an uncoordinated manner or in isolation. Hence, it is crucial to create collaborative networks between academics and connect them with one another to strengthen involvement in ESD [52]. Further, it is evident that although substantial space is given for sustainability concepts, it is still limited. Hence, more improvements are

necessary, considering that it is a compulsory requirement. The academics specified that it is theoretically adequate but not practically so, and further highlighted the need to update every syllabus.

Basically, different kinds of models for teaching and learning are required to meet the needs of the students, and it depends on many factors. Additionally, variations in methods help students employ and develop different learning processes, making them grow as learners, and enhancing their skills and capacities to learn and think [16]. During the discussion, project/problem-based learning and case studies were suggested by a majority of the academics as the most appropriate pedagogical approach to deliver sustainability concepts. The literature suggests that case studies are a productive approach to teaching about sustainability and teaching for sustainability. Similarly, role play, discussions and debates, and field visits were also recommended as effective approaches by many of the academics. Online simulations and business games were also favoured. In addition, sustainability scholars have pointed to experiential learning strategies as ways to empower, engage, and motivate students while also disposing of the typical compartmentalization between action and education [14].

Although the lecture method is considered traditional and still applies in all types of education, many prefer it for use in teaching sustainability. Seminars, tutorials, and mind mapping were the least recommended approaches. Remarkably, one answered with a "no idea", and it acknowledges the capacity of academics to develop students' sustainability practices while highlighting the importance of timely professional training. As Seatter and Ceulemnas [9] argued, the use of a particular methodology is highly dependent on the target (pedagogical and educational goals) and situational specifics (regarding students, teachers, and the learning environment) in which they will be used. Hence, if the academics are not aware of the applicable methodologies to be used, or if they stick to the same pedagogy for every lesson or activity during the teaching–learning process, it would hinder the achievement of situation-specific educational goals. Universities in the 21st century are obliged to train the younger generation to face the challenges to come, and that demands the application of new educational practices and models in the teaching–learning process to make it more productive. Hence, there is a rising need for updating knowledge and professional practices. The possible reasons that academics found for not including SDGs in their activity may have been the consequences of lack of training, opportunities, materials, time, and unawareness of the current trends in the field. For this reason, it is essential to train them, and motivate them to change their practices and attitude. Adding value to activities related to the integration of SDGs in the university curriculum is also needed.

5.2.4. Believes in Embedding SD into Subjects and Teaching as a Separate Subject

The very nature of sustainable development is complex, and multidisciplinary at many levels [53]. Almost all the academics who participated in the conversation suggested that embedding it into subjects is the best way to improve the efficiency of passing sustainability concepts to students at the university level. At this point, they proposed that embedding the concepts is more efficient if it is performed in combination with problem/project-based learning, research case studies, fieldwork assignments, and assessments on the subjects. Contrastingly, a few think that teaching it as a separate subject would be more effective. However, for a better sustainability learning experience, different subjects and disciplines need to be integrated and university classes need to be connected to real-world problems and actors. This requires applying the principles of interdisciplinary, trans-disciplinary, and self-regulated learning [9].

5.2.5. Contribution of Academic and Non-Academic Activities at the University to Enhance Knowledge and Skills Needed for SD

For the question on the status of current academic activities to enhance knowledge and skills needed for sustainability development, it was revealed that the space given for sustainability concepts was either less, moderate, or average but not adequate. Hence there

is room for improvement. Furthermore, as shown at the moment, there are some initiatives but they are still isolated and need to be connected with the mainstream across faculties, departments, and even degree program level at universities. Nevertheless, they are trying their best to contribute the knowledge and skills enhancement needed for sustainability development through most academic activities.

We then tried to find out more about the opportunities provided by universities to students to contribute their knowledge and skills for becoming a part of the journey to sustainability. It was revealed that students benefit from volunteer projects (projects as general electives and assignments of core modules), social activities, clubs, industrial training, internship programmes, scientific research opportunities, field visits, competitions based on sustainable concepts, seminars, lectures, and other university/faculty-level sustainability initiatives.

The academics said: "It's not something to teach. But it's something to feel. We should make them feel and get involved in it". There are many opportunities in the industry and civil organizations to learn and practice sustainability too. However, two participants stated that they are not aware of such opportunities for the students, and another said it is not applicable. It seems that there is room for improvement in their way of thinking and practices as academics in order to create a new educational paradigm ESD.

Integrating sustainability concepts in higher education has been studied in many contexts. Providing empirical evidence for its effectiveness, Qu et al. [54] observed significant changes in the knowledge and attitudes of students after integrating engineering curriculum with sustainability concepts. And that would be equally applicable for other disciplines too. On the other hand, teaching is not the only area of activity where sustainable development is becoming increasingly important. Research at many universities is playing an increasingly important role, both in terms of academics and financial support [48]. On the whole, higher education for sustainability should potentially support and facilitate transformative learning that demands asking critical questions, continually search for new sources and ideas, and encourage creativity and organizational learning [9]. Vice versa, the very nature of sustainability as a contested, multilayered and multifaceted subject provides rich opportunities for critical thinking and transformative learning [53].

5.2.6. Suggestions to Improve Academic Activities/Courses Suite to Achieve Sustainability Locally and Globally

Referring to several studies, Qu et al. [54] specified that embedding sustainability into the curriculum does not merely mean an add-on of new content to enhance the existing knowledge base of sustainability. Rather, it is a fundamental element. Consequently, it is important to automatically initiate a transformational routine, where there is expectation that knowledge will be facilitated toward developing sustainable behaviours.

When considering the world scenario, various attempts have been made to uplift the concept of ESD in university education. During the conversations, several suggestions were made by the academics to improve the academic activities/courses suite to achieve sustainability locally and globally. Basically, partnerships at all levels are considered prominent while integrating the sustainability concept as the basis of every discipline related to development to enhance the credibility of the subject. Along with these, creating opportunities to update and increase the awareness of academics and students in other countries is also seen as a timely requirement.

Besides focusing on curriculum and pedagogical practices, they agreed that curriculum amendments are important because students should be provided with the experience within the discipline. Introduction of practically oriented disciplines; adding the sustainability concept to teaching and practical activities; conducting specialised workshops; implementing modern teaching concepts (PBL, case studies); encouraging lifelong learning; linking sustainability-related current world issues, challenges, and achievements with academic work; focusing on global trends for sustainability during the teaching–learning process; and providing regular insights on sustainable development were the most com-

mon suggestions made to improve education on sustainability. Other than that, they recommended giving more weight to topics such as "resource and energy sustainability, sustainable consumption and production, environmental sustainability, social sustainability, economic sustainability, and product life cycle sustainability". All in all, it was concluded that integrated and holistic discussion is needed in this case.

According to UNESCO [19], the goal of higher education is to support students in developing the capacity to recognise and understand the complexity of sustainability issues, and think critically about assumptions, biases, beliefs, and attitudes while actively participating in their resolutions. To achieve education in sustainable development, it is also necessary to provide individuals/students more than just the knowledge and skills needed to recognise sustainable development, but the capacity to develop sustainable development practices in their own world too [3].

5.2.7. The Impact of Online/Hybrid Teaching

Due to the prevailing global pandemic, the mode of education has been shifted to digital platforms. As Gonzalez-Gomez and Jeong [55] mentioned, e-learning and online learning are now considered as teaching–learning processes based on a proper educational model, which allows flexible and pertinent learner-centred education due to ICTs in sustainability education. Within that environment, embedding sustainability experiences in learning and teaching practices is really challenging. Hence the impact of online/hybrid learning was discussed, and it resulted in mixed views without being biased towards either end.

Basically, online mode has been taken up as a way to continue education at the global level, and accelerate the learning and teaching practice significantly through the past two years. It has had a mixed impact, affecting students in both negative and positive ways. However, the impact of blended learning on SD is very high, and it reinforces the process that emerged in the discussions. Furthermore, hybrid teaching has been accepted as the most efficient and effective alternative, although it has changed the landscape of the journey to embedding sustainability in learning and teaching practices. Another argument put forward was the impact of resource availability to conduct hybrid teaching–learning, and the need for improvement to achieve productive education. So there is a greater requirement to enhance aspects such as resources, and effective ways to convey SD ideas to the audience.

On the other hand, it was stated that "online teaching provides fewer opportunities to deliver and practice SD concepts due to limited opportunities to communicate and conduct fieldwork". Hence, it is suggested that effectiveness has decreased as online platforms are good for discussions but not practice. Remarkably, some contradicted both the positive and negative observations mentioned above, arguing that impact is based on the teacher and not on the mode of teaching. Further, it was reasoned out that "if the course content is delivered and there is emphasis on the value of the subject, it does not matter how the lectures are delivered".

"No idea" was also received as a response, and it once again brought into question the up-to-dateness of the academic. It also brought into question the capabilities and attitude of the academic as a responsible professional. The responsibility of the university is not merely to make students knowledgeable, but also to guide them into finding new knowledge and competencies, and making them aware of the changes and challenges. To facilitate this, university academics need to have a clear perception of the trends and changes in the contemporary world.

6. Conclusions

Science and technological advancements have raised the living standards of people enormously, and this, in turn, has resulted in many global issues. In such a scenario, transforming mere development into sustainable development became a matter of universal

concern. Simultaneously, education started being recognised as the means for building a future with balanced economical, ecological, and social sustainability.

Accordingly, it is important to develop learning environments that encourage students to acquire knowledge and skills while developing the right attitude. According to Mulder [56], sustainability demands a specific kind of learning. Some authors call for a deep change in society to achieve a sustainable society. "Sustainable development is not just a matter of acquiring some extra knowledge. Attitude is also important. Moreover, it is often necessary to change social structures", they say.

In the way forward to sustainability, empowering present and future generations with STEM knowledge and skills is recognised as essential. Therefore, there is a requirement for high-quality STEM education through which students experience innovative pedagogical strategies, interactive learner-centred teaching, and learning environments, to meet the requirements of ESD. Traditional teacher-centred teaching and learning methods limit opportunities for experiential learning, critical thinking, reflective reasoning, and involvement in solving complex problems and growing into a responsible citizen. Hence, Pahnke et al. [8] proposed that STEM experience should promote inquiry-based learning and scientific thinking, and encourage interactive, learner-centred teaching that enables exploratory, action-oriented, reflective, and transformative learning. Notably, the need for learner-centred innovative approaches for sustainability-oriented higher education has emerged from the literature and from discussions with academics.

To achieve the goals of education for sustainability, it is obligatory to implement an appropriate pedagogy in the teaching–learning process. In the sense of pedagogy for sustainability, it is mainly problem/project-based learning, real-world or experiential learning, case studies, and e-learning that can develop outcomes in the form of changes in individual behaviour towards sustainability goals. They enhance the domains of knowledge, skills, and attitudes expected in ESD. However, when analysing pedagogical approaches and their suitability to teaching/learning SD, the traditional lecture method is still in practice. Seatter and Ceulemans [9] confirmed it further, highlighting that current sustainability teaching in higher education pedagogy lacks the sustenance to facilitate sustainability thinking and behaviour, and often is stymied by a transmissive and lecture-driven delivery. Hence, there is consensus about the need to move from the traditional way to an alternative one so as to allow students to achieve SD competencies in both cognitive (knowledge and understanding) and meta-cognitive (skills and abilities and attitudes) domains. However, all pedagogical methods will not be suitable for every subject, target group, and culture they are going to be implemented on. Therefore, the pedagogy needs to be selected suitably. Susilwati et al. [33] suggested a pedagogy for sustainable development that consisted of four components, which are (1) system thinking and understanding of interconnectedness, (2) long-term, foresighted reasoning, and strategizing, (3) stakeholder engagement and group collaboration, and (4) action orientation and change agent skills.

Attaining sustainability is a long-term process, and education is a pivotal factor in it. It also depends on the collective participation of all the individuals involved, especially teachers and students. Segalàs et al. [57] found that students perceived sustainability as mainly related to technology, and saw little relevance in social and attitudinal aspects. Seatter and Ceulemans [9] also saw that challenges to teaching sustainable development in higher education could mean that students—as future citizens—are left without insight, commitment, or any sense of their position with regard to meaningful beliefs and actions on sustainability. Hence, to achieve education for sustainability, the development of a proper curriculum that has the potential to enhance skills for sustainability is a necessity. Another important requirement for meaningful sustainability curriculum transformation is the involvement of academics. According to Zamora-Polo and Martín [52], academics are very important and relevant in the whole teaching–learning process because they organise the teaching activity, and programme the learning plan that students need to take to achieve success. Barth [16] pointed out that lack of training and different academic backgrounds may also become barriers. Other than that, lack of knowledge of SD and interdisciplinary

competence, lack of interest and understanding, and limitations placed on research and further studies are also in the line. On the other hand, as Zamora-Polo and Martín [52] stated, activities promoting sustainability have traditionally not been valued in teachers' curricula. In that case, motivating for attitudinal change, showing readiness to work across disciplinary boundaries, and providing the required facilities, besides training and funding, are required to overcome the issue. On the whole, individual and collective actions bring about the transformation in higher education, promoting learning for sustainable development. Therefore, teachers, education policymakers, and administrators should go for timely reforms in every context.

The establishment of education for sustainability is hindered by many major and minor factors, with geographical, political, and socio-economical inequalities at the forefront. Most significantly, with the pandemic, education has moved to virtual mode, specifically impacting developing countries due to their lack of resource availability, readiness, and other factors. Thus, more efforts are needed to reduce differences around the world. Additionally, there has been high recognition of science, technology and instrumental knowledge to the detriment of human development and related aspects such as ethics, values, and social knowledge. Transforming education is the biggest deciding factor for transforming societal systems, and as the means for meaningful development, the requirement for sustainability education needs to be addressed with the re-orientation of STEM education in combination with other areas such as sociology and humanities. On the whole, to create a more sustainable world, individuals need to equip themselves with the requisite knowledge, skills, values, and attitudes that will empower them to contribute to sustainable development, and that can be achieved only through the collaborative effort of all participants.

Author Contributions: Conceptualisation, K.A.A.G.; methodology, S.C.P.D. and K.A.A.G.; formal analysis, S.C.P.D. and S.Y.E.; investigation, S.C.P.D. and K.A.A.G.; resources, K.A.A.G.; writing—S.C.P.D., K.A.A.G. and S.Y.E.; project administration, K.A.A.G. and S.Y.E. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Basiago, A.D. Economic, social, and environmental sustainability in development theory and urban planning practice. *Environmentalist* **1998**, *19*, 145–161. [CrossRef]
2. Stakeholder Forum. A Pocket Guide to Sustainable Development Governance. 2011. Available online: https://www.circleofblue.org/wpcontent/uploads/2012/07/PocketGuidetoSDGEdition2webfinal%E2%80%93Stakeholder-Forum.pdf (accessed on 18 November 2021).
3. UNESCO. *Education for Sustainable Development Sourcebook. Education for Sustainable Development in Action. Learning & Training Tools N° 4–2012*; UNESCO: Paris, France, 2012.
4. Mensah, J. Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review. *Cogent Soc. Sci.* **2019**, *5*, 1653531. [CrossRef]
5. Nordén, B.; Avery, H. Global Learning for Sustainable Development: A Historical Review. *Sustainability* **2021**, *13*, 3451. [CrossRef]
6. UNESCO. Bonn Declaration. In Proceedings of the UNESCO International Experts Meeting on Technical and Vocational Education and Training: Learning for Work, Citizenship and Sustainability, Bonn, Germany, 25–28 October 2004. Available online: https://unesdoc.unesco.org/ark:/48223/pf0000140586 (accessed on 15 December 2021).
7. UNESCO. The UN Decade of Education for Sustainable Development (DESD 2005–2014). 2007. Available online: https://unesdoc.unesco.org/ark:/48223/pf0000154093 (accessed on 15 December 2021).
8. Pahnke, J.; O'Donnell, C.; Bascope, M. *Using Science to Do Social Good: STEM Education for Sustainable Development. Position Paper Developed in Preparation for the Second "International Dialogue on STEM Education" (IDoS)*; Haus der Kleinen Forscher: Berlin, Germany, 2019.
9. Seatter, C.S.; Ceulemans, K. Teaching Sustainability in Higher Education: Pedagogical Styles that Make a Difference. *Can. J. High. Educ.* **2017**, *47*, 47–70. [CrossRef]
10. Zizka, L.; McGunagle, D.M.; Clark, P.J. Sustainability in Science, Technology, Engineering and Mathematics (STEM) programs: Authentic engagement through a community-based approach. *J. Clean. Prod.* **2020**, *279*, 123715. [CrossRef]

11. McGunagle, D.; Zizka, L. Employability Skills for 21st Century STEM Students: The Employers' Perspective. *High. Educ. Ski. Work-Based Learn.* **2020**, *10*, 591–606. [CrossRef]
12. Dotson, M.E.; Alvarez, V.; Tackett, M.; Asturias, G.; Leon, I.; Ramanujam, N. Design thinking-based stem learning: Preliminary results on achieving scale and sustainability through the IGNITE model. *Front. Educ.* **2020**, *5*, 14. [CrossRef]
13. Sprain, L.; Timpson, W.M. Pedagogy for Sustainability Science: Case-Based Approaches for Interdisciplinary Instruction. *Environ. Commun. J. Nat. Cult.* **2012**, *6*, 532–550. [CrossRef]
14. Redman, E. Advancing educational pedagogy for sustainability: Developing and implementing programs to transform behaviors. *Int. J. Environ. Sci. Educ.* **2013**, *8*, 1–34.
15. Hasanah, U. Key definitions of STEM education: Literature review. *Interdiscip. J. Environ. Sci. Educ.* **2020**, *16*, e2217. [CrossRef]
16. Basiago, A.D. Methods of defining 'sustainability'. *Sustain. Dev.* **1995**, *3*, 109–119. [CrossRef]
17. Smith, C.; Watson, J. STEM: Silver Bullet for a Viable Future or Just More Flatland? *J. Futures Stud.* **2018**, *22*, 25–44.
18. Hamilton., J.; Thomas, J.P. Sustainability Education: The What and How for Mathematics. *Primus* **2014**, *24*, 61–80. [CrossRef]
19. Zizka, L.; McGunagle, D.M.; Clark, P.J. Sustainability in STEM higher education: Making social change together. *J. High. Educ. Theory Pract.* **2018**, *18*, 121–132.
20. Davis, J. ESD starts where STEM stops: Integrating the social sciences into STEM. In Proceedings of the 2nd International STEM in Education Conference, Beijing, China, 24–27 November 2012; Beijing Normal University: Beijing, China, 2012; pp. 177–183.
21. Taylor, C.H. Quantitative Reasoning and Sustainability. *Numeracy* **2012**, *5*, 1. [CrossRef]
22. Shephard, K. *Sustainability and ES/ESD Missions: Where Are We Now, How Did We Get Here and Where to from Here? Higher Education for Sustainable Development*; Palgrave Macmillan: Basingstoke, UK, 2015; pp. 13–19.
23. Leifler, O.; Dahlin, J. Curriculum integration of sustainability in engineering education—A national study of programme director perspectives. *Int. J. Sustain. High. Educ.* **2020**, *21*, 877–894. [CrossRef]
24. Franco, I.; Saito, O.; Vaughter, P.; Whereat, J.; Kanie, N.; Takemoto, K. Higher education for sustainable development: Actioning the global goals in policy, curriculum and practice. *Sustain. Sci.* **2019**, *14*, 1621–1642. [CrossRef]
25. Yean, A.S. Greening STEM: A Theoretical Exploration for the Malaysian Context. *J. Int. Comp. Educ.* **2021**, *10*, 1802–2232. [CrossRef]
26. Weiss, M.; Barth, M.; Wehrden, H. The patterns of curriculum change processes that embed sustainability in higher education institutions. *Sustain. Sci.* **2021**, *16*, 1579–1593. [CrossRef]
27. Makgato, M. STEM for Sustainable Skills for the Fourth Industrial Revolution: Snapshot at Some TVET Colleges in South Africa. In *Theorizing STEM Education in the 21st Century*; IntechOpen: London, UK, 2019. [CrossRef]
28. Higher Education Funding Council for England (HEFCE). 2009. Available online: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/247862/0002.pdf (accessed on 10 December 2021).
29. Association for the Advancement of Sustainability in Higher Education (AASHE). Available online: www.AASHE.org (accessed on 24 December 2021).
30. Winter, J.; Sterling, S.; Cotton, D. *7 Steps to Embedding Sustainability into Student Learning*; Educational Development, Plymouth University: Plymouth, UK, 2015. Available online: https://www.plymouth.ac.uk/uploads/production/document/path/3/34 09/595997_261396_7_Steps_to_Embedding_Sustainability_into_Student_Learning_1214_BOLD.pdf (accessed on 15 December 2021).
31. Cotton, D.R.E.; Winter, J. *It's Not Just Bits of Paper and Light Bulbs: A Review of Sustainability Pedagogies and Their Potential for Use in Higher Education*; Sustainability Education; Routledge: London, UK, 2010.
32. Tilbury, D. Higher Education for Sustainability: A Global Overview of Commitment and Progress. Higher Education's Commitment to Sustainability: From Understanding to Action. *High. Educ. World* **2011**, *4*, 18–28.
33. Susilowati, I.W.; Hastuti, P.W. Development the Science Learning Plan Based on Pedagogy for Sustainability to Grown Environmental Literacy Students. International Seminar on Science Education. *IOP Conf. Ser. J. Phys.* **2019**, *1233*, 012108. [CrossRef]
34. Westbrook, J.; Durrani, N.; Brown, R.; Orr, D.; Pryor, J.; Boddy, J.; Salvi, F. *Pedagogy, Curriculum, Teaching Practices and Teacher Education in Developing Countries*; University of Sussex: Sussex, UK, 2013.
35. Bernstein, B. *Pedagogy, Symbolic Control and Identity*; Rowman & Littlefields: London, UK, 2000.
36. Suh, H.; Han, S. Promoting Sustainability in University Classrooms Using a STEM Project with Mathematical Modeling. *Sustainability* **2019**, *11*, 3080. [CrossRef]
37. Schoolman, E.D.; Guest, J.S.; Bush, K.F.; Bell, A.R. How interdisciplinary is sustainability research? Analyzing the structure of an emerging scientific field. *Sustain. Sci.* **2012**, *7*, 67–80. [CrossRef]
38. Marieta, C.; León, I.; Millán-García, J.A.; Martín-Garín, A. Education for sustainable development in building higher studies. Education for sustainable development in building higher studies. *Adv. Build. Educ.* **2021**, *5*, 23–31. [CrossRef]
39. Brundiers, K.; Wiek, K.; Redman, C.L. Real-world learning opportunities in sustainability: From classroom into the real world. *Int. J. Sustain. High. Educ.* **2010**, *11*, 308–324. [CrossRef]
40. Petrun Sayers, E.L.; Craig, C.A.; Skonicki, E.; Gahlon, G.; Gilbertz, S.; Feng, S. Evaluating STEM-Based Sustainability Understanding: A Cognitive Mapping Approach. *Sustainability* **2021**, *13*, 8074. [CrossRef]
41. Dawe, G.; Jucker, R.; Martin, S. Sustainable Development in Higher Education: Current Practice and Future Developments. A Report for The Higher Education Academy. 2005. Available online: https://www.heacademy.ac.uk/system/files/sustdevinHEfinalreport.pdf (accessed on 24 December 2021).

42. Shephard, K. Higher Education's Role in 'Education for Sustainability'. Australian Universities' Review. 2010. Available online: https://files.eric.ed.gov/fulltext/EJ877043.pdf (accessed on 5 January 2022).
43. Hansen, K.; Dahms, M.-L.; Otrel-Cass, K.; Guerra, A. *Problem Based Learning and Sustainability: Practice and Potential*; Faculty of Engineering and Science, Aalborg University: Copenhagen, Denmark, 2014.
44. Dobson, H.E.; Tomkinson, C.B. Creating sustainable development change agents through problem-based learning: Designing appropriate student PBL projects. *Int. J. Sustain. High. Educ.* **2012**, *13*, 263–278. [CrossRef]
45. Peter, P.; Reid, A. What on earth is sustainability in mathematics? *N. Z. J. Math.* **2003**, *32*, 135–144.
46. Hardin, R.; Sustainab, M. Towards a revolution in sustainability education: Vision, architecture, and assessment in a case-based approach. *World Dev. Perspect.* **2016**, *1*, 58–63. [CrossRef]
47. Wei, C.A.; Brown, M.; Wagner, M. Pursuing the Promise of Case Studies for Sustainability and Environmental Education: Converging Initiatives. *Case Stud. Environ.* **2018**, *2*, 1–8. [CrossRef]
48. Davis, U.G. The role of case studies for the integration of sustainable development into the education of engineers. *World Trans. Eng. Technol. Educ.* **2006**, *5*, 159.
49. Maher, R.; Maher, M.; Mann, S.; McAlpine, C.A. Integrating design thinking with sustainability science: A Research through Design approach. *Sustain. Sci.* **2018**, *13*, 1565–1587. [CrossRef] [PubMed]
50. Sadowski, J.; Seager, T.P.; Selinger, E.; Spierre, S.G.; Whyte, K.P. An Experiential, Game-Theoretic Pedagogyfor Sustainability Ethics. *Sci. Eng. Ethics* **2013**, *19*, 1323–1339. [CrossRef] [PubMed]
51. Altomonte, S.; Logan, B.; Feisst, M.; Rutherford, P.; Wilson, R. Interactive and situated learning in education for sustainability. *Int. J. Sustain. High. Educ.* **2015**, *17*, 417–443. [CrossRef]
52. Zamora-Polo, F.; Sánchez-Martín, J. Teaching for a Better World. Sustainability and Sustainable Development Goals in the Construction of a Change-Maker University. *Sustainability* **2019**, *11*, 4224. [CrossRef]
53. UNESCO. *UNESCO Roadmap for Implementing the Global Action Programme on Education for Sustainable Development*; The United Nations Educational, Scientific and Cultural Organization: Paris, France, 2014.
54. Qu, Z.; Huang, W.; Zhou, A. Applying sustainability into engineering curriculum under the background of "new engineering education" (NEE). *Int. J. Sustain. High. Educ.* **2020**, *21*, 1169–1187. [CrossRef]
55. Jeong, J.S.; Gonzalez-Gomez, D. Assessment of sustainability science education criteria in online-learning through fuzzy-operational and multi-decision analysis and professional survey. *Heliyon* **2020**, *6*, e04706. [CrossRef]
56. Mulder, K. *Sustainable Development for Engineers*; Greenleaf Publishing: Sheffield, UK, 2006.
57. Segalas, J.; Mulder, K.F.; Ferrer-Balas, D. What do EESD "experts" think sustainability is? Which pedagogy is suitable to learn it? Results from interviews and Cmaps analysis gathered at EESD 2008. *Int. J. Sustain. High. Educ.* **2012**, *13*, 293–304. [CrossRef]