Abstract: In an era marked by unprecedented global challenges, including environmental degradation, social inequalities, and the rapid evolution of technology, the need for innovative educational approaches is critical. This conceptual paper explores the intersection of sustainability, creativity, and technology for education, focusing on artificial intelligence (AI) as an example. We propose a framework that synthesizes sustainability principles and creative pedagogies, detailing its components to guide the integration of AI into sustainability education. The paper illustrates how blending creative pedagogies with the notion of sustainability as a frame of mind offers a framework that allows teachers to support creative learning and problem solving, with and through technology. Using the example of AI technology, we illustrate the potential benefits and inherent challenges of integrating new technologies into education. Generative AI is a cogent example, as it presents unique opportunities for personalizing learning and engaging students in creative problem solving around sustainability issues. However, it also introduces significant environmental and ethical concerns to navigate. Exploring the balance between technological innovation and sustainability imperatives, this paper outlines a framework for incorporating technology into education that promotes environmental care with creative exploration. Through a synthesis of sustainability principles and creative pedagogies, we highlight the benefits and challenges of using AI in education, offering strategic insights to leverage technology for a sustainable and just future.

Keywords: sustainability; sustainable education; creativity; creative mindset; teachers; teaching; AI; artificial intelligence; digital technologies

1. Introduction

As society confronts global challenges like environmental degradation and rapid technological changes, the need to integrate creativity in sustainability education is imperative, particularly given the tensions and opportunities afforded by new technologies like AI. This conceptual article tackles the problem of how current educational systems, which often employ traditional pedagogical approaches, fall short in preparing students to address interconnected global issues. We offer a conceptual framework that blends creative pedagogies with sustainability education elements and explore the role of artificial intelligence (AI) in this context. AI has the potential to innovate and support problem solving within sustainability, even while essential tensions and contradictions emerge from AI’s environmental impact. We specifically explore the following questions: What are the roles of creativity and technological integration in crafting educational strategies that prepare future generations for complex global challenges? What kind of framing strategies might support the development of creative pedagogies in sustainability education, particularly in navigating sustainability tensions posed by technologies like AI? This paper proposes a novel framework that synthesizes sustainability principles, creative pedagogies, and technological innovations, aiming to guide educators and researchers in leveraging AI’s
transformative potential responsibly. This discussion sets the stage for an examination of AI’s benefits and challenges, strategies for its integration, and reflections on future research on creativity and sustainability in educational technology.

Although technological development often benefits society, it has also resulted in environmental harm and widened socio-economic divides [1]. Globally, society’s current path is unsustainable, underscoring the urgent need for innovative, lasting solutions. Tackling complex environmental and social challenges requires creative mindsets, knowledge, and skills aimed at deliberate, value-driven actions. Education is crucial for instilling such knowledge, skills, values, and creativity, yet traditional pedagogical approaches do not necessarily prepare students to deal with interconnected problems [2]. The shortcomings of current educational systems may even contribute to these issues by neglecting them. The importance of sustainability education is magnified when we consider sustainable development as a multifaceted creative problem-solving task, spanning social, economic, cultural, environmental, and educational realms [3]. By integrating sustainability into curricula, education can acknowledge the link between human and ecological systems and commit to a fairer, more sustainable future [4]. This calls for a shift towards education that emphasizes creativity and innovation, equipping learners with the creative problem-solving abilities necessary for addressing current and future sustainability challenges.

Technology, in this context, plays a critical role. At one level, technological advancement has led to many of the environmental challenges we face today. Yet, at the same time, technology can also help transform how we think about sustainability by providing new ways for learners to develop the requisite knowledge, skills, and mindsets required to thrive sustainably [5]. We highlight AI as a case in point to demonstrate how technology can offer creative solutions for humanity’s benefit, despite the potential environmental drawbacks. In this article, we begin by defining sustainable education and contextualizing its importance in the face of global challenges. We then discuss the role of creativity in teaching and pedagogy. Discussing Henriksen and Mishra's extant research-based frame for creative pedagogies (real-world applications, intellectual risk-taking, and interdisciplinarity) [6], we demonstrate how it maps onto a conceptual frame for education and sustainability (action, mindset, and values) by Bonnett [4]. By overlaying and intertwining these two existing conceptual frames, we propose a synthesized frame for creativity pedagogy in sustainability education. As an example of how such a framework may apply for a specific technology, we consider generative artificial intelligence. Therefore, we provide some background for AI and its impact on our world. Specifically, we consider strategies for integrating AI responsibly with sustainability concepts given the framework for creative pedagogies (consisting of action, mindset, and values) for sustainability education developed earlier. Our goal is to support educators to address challenges and opportunities for aligning technological advancements with sustainability goals. Finally, we conclude by reflecting on the implications for future research and practice. Through our framing (action, mindset, and values) we aim to contribute to the dialogue on educational futures in a technologically driven world, advancing sustainability and creativity, to harness the transformative potential of technology.

2. Principles for Sustainability Education

Sustainability has become a critical focus in response to the escalating global climate crisis. It hinges on values-based principles that prioritize the well-being of ecosystems, social dynamics, ethics, and vigilance [7], emphasizing the importance of caring for the environment, fostering equitable societies, and maintaining ethical standards in human endeavors. At its core, sustainability is not merely a concept, but a way of action intertwined with a mindset [4]. Thus, it is centered on achieving specific goals, with experts leading through stakeholder engagement, enhanced communication, and interdisciplinary collaboration to drive positive change.

In education contexts, inculcating sustainability involves cultivating a compassionate perspective that supports and drives climate activism [4]. Several core habits of mind that the
field has focused on cultivating through education involve courage, dedication to positive change, and curiosity. By encouraging learners to form their own viewpoints through action-oriented sustainability experiences, creative teachers can deepen learners’ understanding of environmental issues and stimulate innovative solutions [8]. Teachers often use varied methods, from solo exploratory tasks that promote personal responsibility and creativity, to group projects that encourage teamwork and collaborative problem solving—both inside the classroom and through outdoor activities. For instance, project-based learning initiatives like creating school community gardens have been used as practical approaches to instill compassion and environmental stewardship in students, while allowing students to explore a range of subject matter concepts (e.g., health/wellness, nutrition, environmental impact, natural sciences and other STEM, etc.) and also build community and shared responsibility [9]. Yet, while these kinds of project-based approaches have an important place in sustainability education, teachers often struggle to conceptualize creative or innovative approaches to sustainability pedagogy. Further, the field lacks a comprehensive framework that directly applies creative education to sustainability as a subject.

Creative interdisciplinary real-world learning experiences are central to the tenets of sustainability education, given that sustainability applications and problems in the real world tend to be complex and integrate varied disciplines [10]. In that sense, transdisciplinary collaboration must be a cornerstone for driving long-term, progressive change in sustainability efforts [11]. By incorporating diverse perspectives from various stakeholder groups, educators can potentially facilitate the co-creation of climate solutions and explore creative approaches to address sustainability challenges. For instance, in Henriksen and Mishra’s study of award-winning creative teachers, science educators described the success of activities like alternative energy debates, where students research and take on different roles (politicians, community members, energy industries) [12]. While their study is not situated in any one content area, it is particularly relevant in the context of sustainability, given the focus on creative teaching and learning as being cross-disciplinary and involving intricate links among social, economic, and environmental factors. In this paradigm, creative learning projects inherently tie together multiple disciplines and are situated with real-world relevance. However, one of the challenging points of their work is that this principle looks inherently different across different contexts, given all the variables in play in any learning setting. This means that teachers may benefit from specific applications of their creative pedagogies within their own disciplines. What real-world learning looks like is variable and inimitable. In the context of sustainability education, real-world learning often requires projects that have tangible outcomes or influences in communities or relevance in students’ lives, giving students a voice in sustainability efforts (e.g., evaluating their school’s sustainability practices and proposing improvements, engaging in projects with local or community environmental applications, etc.). While this kind of pedagogy can instill a sense of agency and emphasize transdisciplinary learning [13], developing such creative projects or pedagogies is often challenging for teachers, given the lack of extant conceptual work on creative pedagogies that specifically account for sustainability elements as a frame. This gap is even more apparent in factoring in the challenges of integrating new technologies, like AI, in sustainability education practice.

Sustainability education has unique foci that are not necessarily present in traditional siloed subject matter learning. For instance, the role of interpersonal connectedness and understanding the deep ties between individuals, communities, and the larger ecosystem are critical elements of sustainability learning, in aiming to foster a sense of collective responsibility and empower learners to act as catalysts for positive change. While such elements may appear in other subject matter learning at certain points, they are fundamental to the value-centered approach of sustainability learning. This points to the complexity of teaching sustainability to students in ways that take a holistic perspective on systems and pinpointing leverage points [11] and suggests that creative pedagogical approaches are needed to support students’ own creative development as sustainability-minded thinkers and citizens.
One key theoretical frame for conceiving of sustainability in education was laid out by Bonnett in viewing it as a trifold frame of mind [4]. Based on Bonnett’s comprehensive review, he describes the emergence of a framework to guide sustainability education, focused on three pillars: action, mindset, and values. Bonnett’s work does not deal with creativity, however, but it does critically evaluate the notion of sustainable development. He argues that sustainability is not merely a policy but an imperative to educate learners to view sustainability as an integral element of human consciousness and our relationship with nature. In Bonnett’s work, a threefold frame emerges based on these foundations:

1. **Action**: The encouragement of practices that reflect a deep understanding of and respect for the natural world. This involves integrating sustainability into everyday behaviors, decision-making processes, and educational curricula, aiming to foster actions that have a positive impact on the environment.

2. **Mindset**: The cultivation of a sustainability mindset among students and educators—a shift from viewing nature as a resource to be exploited to seeing it as a complex system with which humans are intricately inter-connected. This mindset emphasizes the importance of a holistic view of the environment, recognizing the impact of our actions on the planet.

3. **Values**: The embedding of values that support a sustainable future into the educational process. This includes developing empathy for non-human entities, understanding the intrinsic value of all forms of life, and recognizing the ethical obligations that arise from our interconnectedness with nature. These values underpin the mindset and actions necessary for a sustainable lifestyle.

Again, however, what is missing here is clarity about pedagogical elements of developing these three elements. Bonnett’s perspective on sustainability provides a framework for addressing challenges related to the climate crisis and similar socio-ecological, but it does not speak to the skills or strategies that teachers might actually apply to engage in teaching, learning, or creative thinking. It provides a useful general frame for conceptualizing the goals of sustainability education but could become more powerful for teaching practice when connected to pedagogical concepts, particularly around creativity. Thus, our work in this paper seeks to bridge this gap by combining these three elements of sustainability education with an existing frame for creative pedagogy. In doing so, we (in later sections) aim to provide grounding for the creative teaching in sustainability—noting its utility in navigating technological challenges and tensions, such as AI. We assert that this focus on creative teaching is increasingly important, not only to develop creative approaches for complex problem solving in sustainability, but also to help navigate the tensions and contradictions raised by integration of digital technologies in sustainability learning.

**Technology as a Tension in Sustainability Education**

Technology has a role to play in fostering digital literacy in sustainability education, but it is also a source of tension. In both practical and research settings, digital technologies have been used to support critical thinking and data analysis in sustainability projects. For instance, education initiatives often task students with evaluating local environmental data—such as the Globe Program (https://www.globe.gov/ (accessed on 25 March 2024)), an international science and education program encouraging students and the public to participate in data collection and the scientific process, or Eco-Schools (https://www.ecoschools.global/ (accessed on 25 March 2024)), a global program empowering students to drive change and improve environmental awareness in their school [14,15]. There are a range of such instances of educational technology usage and research in sustainability education and pedagogy [16]. However, there is less education research available that explores the tensions/contradictions of technological implications for sustainability or considers how creativity might help teachers manage such tensions given the repercussions of technologies (like generative AI) in environmental impact, data privacy and ethics, and more. In particular, given the relative newness of AI, there is even less work that considers
the challenges of sustainability education, or provides teachers with a pedagogical frame for creative teaching.

However, digital technologies often have a detrimental environmental impact in terms of their energy consumption, and their development are driven by consumeristic market forces, which has led to some reasonable concerns about their place in sustainability education [17], despite their critical role in the world around us. Sustainability education also deals with more than environmental impact, and similar issues of tension with digital tools like AI can be seen in other sustainability concerns, like issues related to data privacy, algorithmic bias, and the digital divide [18]. In the scope of this article, we do not delve into the myriad of varied issues or sustainability concerns affected by AI. We have focused on (and present further in Section 3) the environmental impacts, given the scale of that concern and its relevance to sustainability. In that sense, we emphasize the urgency of developing creative pedagogical approaches to reflect current data and societal needs, emphasizing sustainability and our intrinsic connection to the environment.

Thus, we see an inherent tension—wherein technological progress actively contributes to numerous environmental issues, but it simultaneously offers unique and relevant opportunities in teaching and learning (which we explore later in the context of sustainability). It has affordances that, if used creatively, can offer opportunities for teachers and learners to engage in possibility thinking, analysis, dialogue, and refinement of new ideas [19]. Teacher creativity is critical here to link sustainability with the generation of fresh ideas [19]. Teacher creativity is critical here to link sustainability with the generation of fresh ideas [19].

3. AI and Its Tensions for Sustainability

The introduction of artificial intelligence (AI) into the educational sector signals a paradigm shift, offering opportunities to enhance teaching and learning processes and foster educational creativity. AI encompasses a wide range of applications that not only transform how educational content is delivered but also how students engage with materials, collaborate, and express their creativity [20].

Most prominently, generative AI (GenAI) and Large Language Models (LLMs) are revolutionizing education. These technologies (such as ChatGPT) have proven their capabilities by achieving feats like passing the US bar exam [21] and the European Exam in Core Cardiology [22]. LLMs, exemplified by the Generative Pre-trained Transformer (GPT), leverage vast datasets to understand and generate human-like language, enhancing natural language processing and enabling tasks like language translation, computer code development, text generation, and sentiment analysis with exceptional accuracy.

3.1. Generative AI in Sustainability Education

Technologies unlock their fullest potential by enhancing human capabilities in previously unimaginable ways. Due to its power in harnessing large amounts of data, its generative capacity to create original content, and its ability to mimic human interactions, GenAI is poised to alter the social and cultural landscape of our world [23]. Unlike earlier technologies, which primarily relied on pre-existing data and straightforward algorithms for tasks like data retrieval and basic processing, GenAI can go beyond the data that it has to extend or extrapolate ideas forward and produce creative content, including text, images, videos, simulations, and more [24].
These capabilities allow for the creation of personalized learning materials, interactive experiences, and novel problem-solving approaches, offering customization and innovation previously unattainable. AI tools through their multimodal capabilities can also enable creative expression and problem solving by providing students with novel ways to explore ideas and alternative possibilities, thereby fostering a deeper understanding and retention of knowledge [25].

Incorporating GenAI into sustainability education opens up a wealth of creative possibilities for engaging students to better understand the complex ecological dynamics and interdependencies that are often difficult to grasp. These could range from developing interactive simulations of ecosystems, modeling the effects of climate change, and exploring human–environment interactions and more [26]. Warr and colleagues [27] highlight AI’s capacity for analytical tasks, noting its ability to detect patterns and apply them in novel contexts, revealing new insights in environmental studies that might otherwise be overlooked. For instance, they note that there are few specific or geographically focused studies (e.g., the effects of mid-range climate change on flooding, specifically on street corners in Des Moines, Iowa), and yet generative AI has enormous capacity to investigate previously unexplored areas:

*Generative AI can make that prediction because it can pull data from topological databases, from meteorological databases… and come up with a forecast that’s beyond gluing together things on the web. It’s actually a powerful form of big data and large language models working together to create something (Harvard scholar Chris Dede, quoted in [27], p. 398).*

Furthermore, AI environments might allow students to experiment with different sustainability practices, observe the consequences of environmental changes, and understand complex ecological interdependencies [28]. Or these tools could generate a variety of problem-solving scenarios that challenge students to come up with creative solutions to sustainability issues (e.g., from designing sustainable cities and developing renewable energy solutions to creating waste reduction plans), and other real-world challenges [29]. AI could be used to generate compelling narratives or interactive stories that highlight sustainability themes, ethical dilemmas, and the societal impact of environmental decisions, or facilitate global collaboration projects by connecting students from different parts of the world to work on sustainability challenges together. It can generate project prompts and dialogue with students, and even translate interactions, allowing students to gain diverse perspectives on environmental issues and work collaboratively on innovative solutions [30].

We also note that while specific AI tools and models continue to evolve at a rapid pace, our discussion focuses on the general capabilities of these technologies (not necessarily specific tools like ChatGPT, Claude, Bing, or any of a variety of other platforms available and constantly emerging). Fundamentally, it is the capabilities of AI tools, like natural language processing, predictive thinking, and pattern recognition, which are pertinent as technological affordances that could support creative and sustainable learning environments. Generative AI systems, which include a range of technologies from basic automated content generators to advanced machine learning models capable of producing highly interactive and adaptive learning materials, offer diverse applications in educational settings. Although the specifics of these tools may change, the principles of how they can be integrated into pedagogical practices remain consistent. By focusing on these foundational principles, our goal is to provide pedagogical guidance, based on principles of creativity and sustainability, that is relevant regardless of future technological advancements.

Despite these pedagogical possibilities, it is also important for us to recognize that there is a less-discussed flip side, or a darker element to the AI narrative. This presents a glaring environmental tension when employing generative AI for learning about sustainability issues. One that underscores the environmental costs of using the technology itself.
3.2. The Problem of AI for Sustainability

Despite its potential benefits in education for sustainability, the implementation of AI in education brings environmental tensions and broader ethical concerns. The energy consumption associated with training and running AI models, alongside e-waste from technological devices, poses significant sustainability challenges \[1\]. These models are trained using a method known as unsupervised learning on vast datasets of text from the internet and other sources. This pre-training phase is computationally intensive and requires sophisticated algorithms to process and learn from the enormous amount of data effectively.

The environmental impact of training LLMs is significant, stemming primarily from the substantial energy consumption required to power the high-performance computing resources. These models are trained on clusters of GPUs or specialized AI hardware for weeks or even months, consuming vast amounts of electricity \[31\]. This energy consumption contributes to significantly rising carbon emissions, as non-renewable energy sources power the majority of the world’s electricity, raising concerns about the sustainability of continuing to develop larger and more complex models \[32\]. Additionally, the cooling systems necessary to dissipate the heat generated by these computing resources further increase energy usage, compounding the environmental impact. Thus, the computational demands of developing LLMs contribute to a substantial carbon footprint, raising concerns about sustainability and environmental responsibility in AI research \[33\]. Furthermore, the social implications of human reinforcement training highlight ethical considerations regarding the use of human feedback to optimize model behavior.

Computing the “true” cost (in terms of technical and human resources) of training these models is a non-trivial problem. It is important to recognize that most of the computing that is needed for these models happens in the “cloud” (i.e., technology that allows users to access and store data, as well as use computing resources over the internet) \[34\]. The “cloud” offers on-demand access to a shared pool of configurable computing resources, such as servers, storage, applications, and services as well as the specialized GPUs and AI processors for the data-intensive and computationally demanding processes needed to train these LLMs \[35\].

What this means, however, is that the carbon footprint of cloud computing now surpasses that of the aviation industry \[36\]. AI use is directly responsible for carbon emissions from non-renewable electricity and for the consumption of millions of gallons of fresh water, and it runs on power-hungry equipment that drive energy use in their building and maintenance \[37\]. A recent MIT review article argues that just one ChatGPT request can produce a carbon footprint that is 100 times larger than that of a typical Google search, and the energy used to train OpenAI’s GPT-3 model is comparable to the yearly energy use of 120 average American homes \[32\]. The review goes on to note that data centers, essential for AI operations, use as much energy as is needed to heat 50,000 houses each year. Collectively, data centers consume over 200 terawatt hours (TWh) of electricity annually, exceeding the energy consumption of certain countries; and the energy use of data centers contributes to 0.3 percent of the world’s total carbon emissions. When we also consider networked devices like laptops, smartphones, and tablets, this figure rises to 2 percent of global carbon emissions. Apart from cooling needs, data centers require a substantial amount of energy since they are built to ensure that customer data and cloud services are always accessible, featuring extensive redundancy. This means that if one system fails, another can instantly replace it, maintaining uninterrupted service. Data centers maintain layers of backup systems: from diesel generators for power to spare servers that can immediately handle computations if needed. Often, only 6 to 12 percent of the energy used is for actual computing, with the rest dedicated to cooling and supporting numerous backup systems to avoid expensive operational interruptions.

This means that AI has a tremendous environmental footprint \[38,39\] that cannot be ignored \[40\] raising significant environmental and ethical concerns. Thus, even as we acknowledge the potential that GenAI has to transform education, we must recognize that
it comes with the responsibility to minimize the technology’s environmental impact. Educators have an opportunity to make learners conscious of these issues and adept at addressing them, requiring a reassessment of our integration of these tools into educational practices.

As we face the essential tension of technological advancement and environmental stewardship, the next move involves reimagining the role of creativity in sustainability education. Creativity not only serves as the catalyst for innovation and problem solving but also as a bridge between the digital and natural worlds, guiding us towards more sustainable and ethical uses of AI [41]. By embracing pedagogical strategies that fuse AI’s capabilities with creative approaches to learning, educators might cultivate a generation of learners equipped to tackle sustainability challenges with technological proficiency and a deep respect for the planet.

This theoretical mapping of creative pedagogy and sustainable education may help to ensure that technological innovations are employed not just to make the process of teaching and learning more efficient. Rather, this creative sustainability frame could support educators in leveraging technology responsibly to advance a more sustainable, equitable, and creative educational practices landscape. The challenge and opportunity lie in consciously designing and implementing educational technologies and pedagogies that embody these synergies, paving the way for a future where education is a driving force for sustainability.

Educators and sustainability practitioners need creativity to navigate the tensions and contradictions of using technological tools which are alternatively both helpful and harmful when it comes to sustainability outcomes. AI can support cognitive affordances or solution seeking, but it can also create harm through environmental degradation or other ethical dilemmas. To try to develop a frame that blends existing creative pedagogies into the desired outcomes of sustainability as a frame of mind, we discuss the existing literature on creativity in education. In doing this, we explicitly bridge this gap by linking theoretical work on creative pedagogies to Bonnett’s frame for sustainable education—to explore an integrated teaching approach. Later, we describe how this framework can be applied in the context of AI within sustainability education.

4. Mapping Creative Pedagogies to Sustainability Education

Embracing creativity for sustainability requires a paradigm shift that involves fundamentally rethinking how we engage students in the learning process. Creativity—or the ability to devise novel and effective ideas and solutions [42]—combined with an ability to see situations and problems with an openness for the new, is essential in addressing complex global and societal challenges (e.g., climate change, wealth inequality, racial injustice, or countless others).

4.1. Creative Pedagogies in Education

Traditionally, PK12 educational systems (and even higher education) tend to reinforce existing knowledge and standard approaches to teaching and learning, where students tend to reproduce pre-existing solutions or develop answer-getting dispositions [43]. The status quo educational focus on standardized learning can hinder opportunities for meaningful learning and the development of student creativity [2], leaving students unprepared to solve complex problems, such as future-oriented sustainability challenges.

Creativity is crucial in addressing sustainability challenges, where the uncertainty of the future demands innovative problem solving for novel or ambiguous situations [44]. In our rapidly changing world—characterized by volatility, uncertainty, complexity, and ambiguity (VUCA) and marked by fast-paced technological advances, globalization, shifting demographics, and economic fluctuations—traditional approaches fall short [45]. Complex problems require new ways of seeing the world—ways of working with pre-existing knowledge while also identifying new patterns, and developing novel, unique, and contextually grounded solutions [46]. Learners need appropriate skills and mindsets to face complex
challenges—to see the emerging contexts through “new” eyes and broader perspectives, to devise creative solutions.

The open-ended nature of creative problem solving often leads to uncertainty and discomfort, prompting individuals and groups to shy away from creative decisions in favor of predictable solutions, despite the potential for greater innovation [47]. The role of teachers is critical in this context, as those who embody, model, and encourage creativity significantly influence their students’ creative thinking, enjoyment, and academic success [2,48]. Creative educators facilitate the reconstruction of knowledge through discovery, prompting students to generate original ideas instead of merely reciting learned information [49]. This approach is crucial for cultivating an educational atmosphere that ignites curiosity, encourages exploration, and nurtures innovative thinking in sustainability.

We highlight a frame for creative teaching developed by Henriksen [20] and Henriksen and Mishra [12], based on an in-depth study of highly creative, accomplished educators (nationally award-winning U.S. teachers). While there are varied possible pedagogical strategies for fostering creative learning, [12] found three common themes that characterized the pedagogical profile of successful creative educators, including: integrating real-world learning, openness to new ideas or intellectual risk-taking, and taking interdisciplinary approaches to content.

Creative teachers take action-oriented approaches to real-world learning applications in their pedagogy. They consistently link learning to real-world applications and scenarios that enhance student engagement and support creative thinking. Some common ways to do so include project-based learning, presenting real-world problems as ways to apply content learning, taking learning outside the physical classroom, and facilitating community partnerships or entrepreneurial projects. Real-world connections challenge students to apply knowledge actively and creatively.

Creative educators demonstrate a mindset of intellectual risk-taking and openness for the new. They understand the importance of cultivating a learning environment that encourages intellectual risk-taking, where students feel comfortable exploring new ideas, expressing themselves, and engaging in creative processes. Such educators model the willingness to make mistakes and learn from them, use more formative assessments, and incorporate open-ended assignments that have no single easy answer, to support intellectual risk-taking.

Creative educators place value on interdisciplinary approaches as central to how teaching and learning happen. They understand the value of making interdisciplinary connections in teaching, as creativity often involves combining ideas from different disciplines. Basic ways of doing this include integrating art and science, music and math, or any way of connecting one subject matter to explain concepts in another (e.g., connecting social justice issues to science learning). Cross-pollinating ideas across disciplines can promote diverse forms of creative expression and problem solving.

Research suggests [12] this profile of creative teaching which, while not all-inclusive of all possibilities for creative pedagogical engagement, does characterize several core areas of conceptual alignment that seem to emerge in creative pedagogy.

4.2. Theoretical Mappings: Frames for Creative Pedagogy and Sustainability Education

Building on this theoretical foundation, we describe how the pedagogical profile of creative educators—characterized by intellectual risk-taking, interdisciplinary approaches, and integration of real-world applications—maps directly onto the sustainability framework of action, mindset, and values. This mapping is not coincidental but reflects a deeply synergistic relationship between the methodologies of creative teaching (drawn from Henriksen [20] and Henriksen and Mishra’s work [12]) and the principles for sustainability as a frame of mind education (drawn from Bonnett’s [4] work).

The attribute of intellectual risk-taking among creative educators fosters a mindset for sustainability among students. This mindset, open to exploring novel solutions and perspectives, is critical in addressing sustainability challenges that require new paradigms. Intellectual risk-taking pushes learners to challenge norms and assess the sustainability
of their actions in a wider ecological and societal context. It develops mental agility and adaptability, essential for nurturing a sustainability mindset geared towards complex problem solving and innovation.

The interdisciplinary focus evident among creative educators aligns with the core values central to sustainability education. These values—respect for nature, equity, and social justice—are inherently interdisciplinary, touching upon ecological, economic, and social dimensions. By adopting interdisciplinary approaches, educators underscore the interconnectedness of these dimensions, thus reinforcing the idea that sustainable solutions must transcend disciplinary boundaries. This approach nurtures a deep appreciation for the diversity of values that guide sustainable decision making, highlighting the importance of a holistic perspective that integrates multiple fields of knowledge.

Further, incorporating real-world applications into teaching mirrors the sustainability framework’s action component, focusing on transforming knowledge and values into tangible actions that support sustainability. Creative educators bring abstract principles to life by applying them in real-world contexts, exemplifying the sustainability framework’s principle of action. They also foster a sense of momentum—as the creative energy of the educator inspires students to take their thinking into the “real world” where students model the engagement through their own advocacy. There is also a domino effect of sustainability learning—where knowledge sharing is passed through different sources to create a wave of reformers who can educate more people.

In synthesizing these mappings, the profile of creative educators may offer a model for enacting sustainability education. This threefold [12] profile of creative educators can be mapped directly onto the threefold frame [4] for sustainability education. By fostering intellectual risk-taking, educators cultivate a mindset open to change and innovation—a mindset that is critical for sustainability. Through interdisciplinary approaches, they highlight the interconnected values that underpin sustainable decision making. By integrating real-world applications into their pedagogy, they inspire students to take action towards a sustainable future. Thus, the pedagogical strategies of creative educators are not just conducive to fostering creativity and engagement; they are essential for imbuing education with the principles of sustainability. See Table 1 which represents several aspects of this theoretical mapping.
Table 1. Action, mindset, and values across creativity and sustainability frameworks.

<table>
<thead>
<tr>
<th>Sustainability Aspect</th>
<th>Creative Teaching Strategies</th>
<th>Bonnett’s Sustainability Framework</th>
<th>Synthesis of Creative Teaching and Sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action</td>
<td>Integration of real-world applications: Creative educators bridge the gap between theoretical knowledge and practical application, demonstrating how sustainability concepts can be applied in real-life scenarios. This hands-on approach equips students with the skills and confidence to take meaningful actions towards sustainability.</td>
<td>Encouragement of practices reflecting understanding and respect for the natural world: Actions informed by a deep appreciation of our interconnectedness with the environment, aiming to foster behaviors that have a positive impact on ecological systems.</td>
<td>Applied Sustainability Actions: Merging real-world applications with the encouragement of environmentally respectful practices empowers students to undertake sustainable actions, rooted in a comprehensive understanding and respect for the natural world.</td>
</tr>
<tr>
<td>Mindset</td>
<td>Openness to intellectual risk-taking: Encouraging a classroom culture where exploring new ideas, questioning established norms, and considering the sustainability of actions in a broader context is valued. This fosters a flexible and adaptable mindset, essential for sustainability.</td>
<td>Cultivation of a sustainability mindset among students and educators: A shift from viewing nature as a resource to be exploited, to seeing it as a complex system with which humans are intricately interconnected, emphasizing holistic views of environmental impact.</td>
<td>Cultivating an Adaptive Sustainability Mindset: Fostering intellectual risk-taking alongside a sustainability mindset encourages a culture of innovation and adaptability, crucial for addressing complex environmental challenges with thoughtful and creative solutions.</td>
</tr>
<tr>
<td>Values</td>
<td>Interdisciplinary approaches focus: Highlighting the interconnectedness of knowledge and fostering an appreciation for the diversity of values guiding sustainable decision making. This approach nurtures a holistic understanding of sustainability challenges, transcending disciplinary boundaries.</td>
<td>Embedding values that support a sustainable future into the educational process: Developing empathy for non-human entities, recognizing the intrinsic value of all forms of life, and ethical obligations arising from our interconnectedness with nature. These values underpin the mindset and actions necessary for a sustainable lifestyle.</td>
<td>Interdisciplinary Values for a Sustainable Future: The integration of interdisciplinary approaches with sustainability values promotes a broad, ethically grounded understanding of sustainability, encouraging students to develop multifaceted solutions that reflect a deep respect for ecological and social interconnectivity.</td>
</tr>
</tbody>
</table>
4.3. Connecting Sustainability and Creative Pedagogies to Generative AI

The table above proposes a synergy between the creative pedagogy frame and the foundational principles of sustainability education. The direct mapping of creative educators’ characteristics onto the sustainability framework underscores the alignment between intellectual risk-taking, interdisciplinary focus, and real-world applications in teaching, with actions, mindsets, and values conducive to sustainability. This delineation [12] of the creative educator’s profile, when juxtaposed with Bonnett’s framework [4] for sustainability, illustrates a pedagogical path that is innovative and grounded in the realities of our ecological and social fabric. This synthesis offers a model for reimagining education in a way that is responsive to the challenges and opportunities of our world, preparing students to become not just learners but active reformers and advocates for a sustainable future.

Sustainability education is inherently connected to the world around us, and a central part of that world involves today’s digital landscape and the many issues that come with it (e.g., privacy, ethics, information access). Moreover, as we consider creative approaches to sustainability education, it becomes apparent that technology has a critical role to play. In the sustainability space, technology is both the cause of a range of sustainability challenges we face, as well as a catalyst for possible solutions. In education, technology also has the potential to transform how we engage in teaching and learning towards more sustainable goals—keeping in mind the tension inherent there. Moreover, in an age of digital proliferation, learners need tools to help them navigate, analyze, and disseminate sustainability-related information, preparing them to leverage technological advancements in crafting creative solutions to environmental issues.

To explore how technology may play out in these sustainability education contexts we focus on one particular technology—generative AI. Artificial intelligence technologies have received significant attention, particularly after the introduction of generative tools (e.g., ChatGPT, DALL-E, etc.). Generative AI could offer unprecedented opportunities to amplify sustainability education efforts by harnessing AI’s transformative affordances to bolster teaching and learning, ushering in a new era of educational creativity and enhanced engagement, even while acknowledging the fundamental environmental challenges associated with AI. As we consider creative approaches to sustainability education, integrating AI could amplify these efforts. The next frontier in sustainability education harnesses the transformative power of AI to bolster teaching and learning, ushering in a new era of educational creativity and enhanced engagement. Generative AI, thus, serves as a case in point of the application of the framework developed above.

5. AI and Technology Use in Creative Sustainability Education

We have examined the connection between two realms of educational theory, blending practices that prepare students not just for academic success but for meaningful creative engagement with the world’s pressing sustainability challenges. The synergy between creative pedagogies and sustainability principles offers a foundation of educational practices related to sustainability, particularly in a complex rapidly evolving technological landscape. We use the example of AI technologies in spaces for educational creativity and sustainability, noting both their areas of potential (data processing, visualizing, dialogue for possibility thinking, augmenting research, scenario simulation/modeling) as well as possible pitfalls.

For education, generative AI in particular is a compelling example of the technological and creative possibilities of the digital landscape [50]. However, within sustainability, this integration is not devoid of challenges. As we have discussed, the environmental impact of AI technologies, alongside their ethical considerations, presents a crucial tension [1]. Balancing the transformative potential of AI in education with the imperative for environmental stewardship and ethical responsibility is complex, and educators require frameworks that can help them make sense of these intersections.

The deployment of AI within the educational sector brings to light significant environmental concerns (e.g., the energy consumption and carbon footprint associated with
training AI models) [36,37]. This raises ethical dilemmas about the sustainability of such technologies in educational contexts aimed at fostering an understanding of and appreciation for ecological balance. Education plays a pivotal role here, aiming to equip learners with the mindsets and values necessary for action, employing sustainability paradigms for creative problem solving with technology. To mitigate negative impacts and leverage technological benefits, both educators and learners need critical thinking skills to navigate conflicts and challenges, and creative thinking to integrate sustainability into the selection, design, and use of educational tools [8]. Raising awareness about the environmental effects of technology, and advocating for intentional, ethical, and creative use, are vital steps towards aligning AI with sustainability objectives [41].

To present a picture of how our integration of creative pedagogy with sustainability education might look in the context of using AI, we offer Table 2, below, as a further extension of the prior table that mapped these theoretical perspectives together. This is not exhaustive of the possibilities, as the potential of AI is significant and ever-expanding, limited only by our conceptions of use.

In the above instance, AI is an example of the potential of technology to embody and enhance creative and sustainable pedagogy. However, given some of the environmental issues or tensions that we have noted, it is essential for educators and students to critically navigate the use of digital tools, employing creativity to harness the technologies for responsible and innovative solutions, all while remaining cognizant of their limitations.

AI’s role in education extends beyond mere automation or efficiency; it serves as a conduit for realizing the synergistic potential of creative pedagogy and sustainability. For instance, AI-powered simulation tools can immerse students in virtual ecosystems, enabling them to witness firsthand the impact of their actions on environmental sustainability. Similarly, machine learning algorithms can analyze vast datasets to uncover patterns in climate change, offering students a concrete understanding of sustainability challenges. By integrating these AI applications into curriculum design, educators can foster an environment where technological innovation directly supports sustainability education goals [51].

Within sustainability education settings, students often engage with futures thinking strategies as integrated subjects, an approach critical for addressing complex global challenges [52]. AI, with its capacity for data analysis and simulation, may be a dynamic tool for such critical engagement, preparing learners to employ futures thinking and sustainability as core components of their educational journey [50]. For example, by leveraging AI to model climate change scenarios or predict the impacts of sustainable practices, students might find different ways to observe and interpret the present world, setting the stage for corrective actions towards a more sustainable future. This involves not just explorative learning but also visionary thinking, supported by AI’s ability to present complex data in accessible and engaging ways.

The cultivation of a sense of self as a learner and an environmentalist is crucial in adopting sustainability perspectives [4]. Here, AI’s role in creating personalized experiences through dialogue may be useful [29]. By facilitating empathy and effective communication through interactive simulations or virtual environments that mimic real-world sustainability challenges, AI enhances the competencies taught through creative education. These skills remain with students long after their formal education, underpinning their lifelong engagement with the sustainability movement.
Table 2. Mapping together creativity, sustainability, and AI integration in education.

<table>
<thead>
<tr>
<th>Sustainability Aspect</th>
<th>Creative Teaching Strategies</th>
<th>Bonnett’s Sustainability Framework</th>
<th>Synthesis of Creative Teaching and Sustainability</th>
<th>AI Integration: Examples of Responsible Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action</td>
<td>Integration of real-world applications</td>
<td>Encouragement of practices reflecting understanding and respect for the natural world</td>
<td>Applied Problem Solving: A pedagogical focus that bridges disciplinary knowledge with actionable sustainability projects.</td>
<td><strong>AI Simulations:</strong> Use AI to create simulations that model environmental impacts, allowing students to explore the consequences of various sustainability actions.</td>
</tr>
<tr>
<td>Mindset</td>
<td>Openness to intellectual risk-taking</td>
<td>Cultivation of a sustainability mindset among students and educators</td>
<td><strong>Innovative and Adaptive Thinking:</strong> Encouraging a mindset that is both open to change and deeply aware of sustainability issues.</td>
<td><strong>AI-Powered Inquiry:</strong> Leverage AI tools to foster inquiry-based learning that challenges students to develop innovative solutions to sustainability challenges.</td>
</tr>
<tr>
<td>Values</td>
<td>Interdisciplinary approaches focus</td>
<td>Embedding values that support a sustainable future into the educational process</td>
<td><strong>Ethical and Interconnected Understanding:</strong> Promoting an education that integrates ethical considerations with a deep sense of global responsibility and interconnectedness.</td>
<td><strong>AI Ethics and Sustainability Projects:</strong> Incorporate projects that require students to evaluate AI tools for their ethical concerns, considerations, and development aspects.</td>
</tr>
</tbody>
</table>
Moreover, being open to new information and actively seeking learning opportunities are essential traits for participating in this movement [8]. AI can support this by offering up-to-date environmental data and research, encouraging students to reprocess and restructure their thoughts in light of the latest findings. When integrated thoughtfully into the curriculum, AI could support the iterative process of meaning-making, fostering shifts in mindset towards more sustainable actions and values. While creativity in education has been a subject of discussion for years, the approach of mapping them onto and blending them into an extant sustainability framework allows for a novel expression of creative practice in sustainability. We point to this particularly in the context of digital technologies, like AI, which have affordances as cognitive tools that help expand human thinking, even while they pose environmental challenges. But the newness of this theoretical blend of creative pedagogy with the sustainable education frame means that it is still untested and requires more attention in practice. As a thinking exercise in considering the actualization of this model, we provide several mini examples as follows.

Creativity and Sustainability Modeled in Practice

As we explore the intersection of artificial intelligence (AI), creative pedagogies, and sustainability education, it becomes crucial to visualize how these concepts can be manifested in educational settings. The following practice examples, though hypothetical and designed to consider these ideas, may help illustrate the potential applications and challenges of implementing our proposed framework. These scenarios provide insights into how AI can be integrated with creative pedagogies to address complex sustainability issues, highlighting both successful implementations and unsuccessful instances where a missing element of the frame leads to a learning deficit. By examining these examples, we aim to consider practical dynamics and outcomes of applying these innovative approaches in diverse educational contexts.

Successful Creative Pedagogies for Sustainability through AI:

Example 1—AI Project on Sustainable Urban Planning:

- **Example:** An interdisciplinary course combined urban planning, environmental science, and AI to enable students to design sustainable city layouts using AI simulations. Students used AI to analyze various data sets including traffic patterns, pollution levels, and green space distributions to design more sustainable urban environments.
- **Outcome:** This project not only applied AI in a real-world context but also encouraged intellectual risk-taking and creativity, as students explored unconventional solutions to urban sustainability. The interdisciplinary approach allowed students to appreciate the complexity of sustainable urban planning and the potential of AI to integrate diverse data for holistic solutions—taking action and shifting their values and mindset about how cities and spaces can be intentionally designed for sustainability with nature.

Example 2—AI-Enhanced Project-Based Learning for Water Resource Management:

- **Example:** High school students used machine learning models to predict seasonal water availability and plan agricultural activities that would maximize water efficiency. The project spanned biology, chemistry, and computer science, with students actively engaging with local farmers to implement their findings.
- **Outcome:** By connecting AI with real-world agricultural challenges and incorporating multiple disciplines, the project fostered a deep understanding of the dynamics of sustainable practices and encouraged students to take intellectual risks by implementing their AI-driven solutions in actual farming practices. When students are engaged in holistic, impactful action, it is possible to see shifts in their mindset and values about how intentional planning can harmonize the effects of farming with water use and availability.
**Unsuccessful AI Practices Missing Elements of Creative Pedagogies**

**Example 1—AI Used for Theoretical Modeling in Climate Education (lacking real-world integration):**

- Example: An environmental science course utilized AI to examine global climate change impacts through theoretical underpinnings/information, without integrating local data or involving students in projects that connect with their community’s specific climate issues.
- Outcome: Although this course approach attempted to incorporate interdisciplinary knowledge (climatology, computer science), the lack of real-world application and intellectual risk-taking could result in disengaged students who struggled to see the relevance of the models to real-world solutions, ultimately limiting their understanding and motivation to act on climate change (and thus lacking in a shift in mindset or values).

**Example 2—AI for Waste Management Education (lacking interdisciplinarity and risk-taking)**

- Example: A sustainability program designed an AI module to educate students about waste management through data analysis. The module processed large datasets to predict waste accumulation but did not incorporate elements from environmental science, public policy, or community planning to provide a holistic view or practical applications.
- Outcome: This project falls short in fostering a comprehensive educational experience. If an AI tool is used in isolation, without encouraging students to think beyond the data or explore creative, interdisciplinary solutions to waste management issues, students are likely to lack in engagement or changes in action, values, or mindset. Here, the lack of intellectual risk-taking and real-world application could lead to a theory-intensive and uninspiring learning experience that fails to prepare students for actual sustainability challenges.

These hypothetical scenarios integrate AI with creative pedagogies in sustainability education as a multifaceted approach to addressing environmental challenges. The goal is to showcase both the transformative potential and the obstacles inherent in applying multiple elements of creative pedagogies, with and through AI technology, in practical settings. Successful applications underline the importance of real-world integration, interdisciplinary collaboration, and fostering an environment conducive to intellectual risk-taking. Conversely, the less successful initiatives highlight critical areas for improvement, particularly the need for deeper engagement with practical applications and more comprehensive interdisciplinary approaches.

In recognizing the transformative potential of AI in education, it is equally important to recognize some of the aforementioned pitfalls, challenges, and ethical considerations. For instance, the use of AI technologies raises concerns regarding data privacy, as educational AI systems often process sensitive personal information [53]. Furthermore, the risk of algorithmic bias cannot be overlooked, as AI systems trained on historically biased data can perpetuate or even exacerbate these biases, affecting minority groups disproportionately and contributing to the digital divide [18].

Furthermore, while AI can potentially enhance the learning experience by providing dynamic content and offering cognitive affordances (pattern recognition, data analysis, unique content generation, and more), its outputs should be considered prompts for further inquiry rather than definitive answers. Generative AI, at its core, relies on data generated by humans, which can inherently carry biases or inaccuracies. If not correctly calibrated, AI systems might produce outputs based on erroneous or biased data, presenting responses it “believes” to be correct, or it has “hallucinated” by fabricating information. AI systems “think” via prediction and lack human insights for conceptual understanding—therefore, it is possible for them to misinterpret or misrepresent information. Humans using AI critically
and creatively need thoughtful preparation and understanding of its affordances and constraints. Therefore, in educational settings, it is essential that AI-generated content is used in conjunction with critical thinking and human oversight. Educators need preparation to guide students not only to engage with AI-generated information but also to critically evaluate and question its validity and relevance to their learning contexts. By doing so, we can leverage AI as a tool to stimulate thought and discussion, ensuring that it serves as a catalyst for deeper understanding rather than a definitive source of knowledge.

These challenges highlight the need for critical use and robust ethical frameworks and strict governance to ensure AI is used responsibly in educational contexts. While those challenges are a complex arena of their own, and the solutions to them are an emerging area that is outside of their paper, it would be remiss of us to not recognize the additional challenges and tensions that they open up. Building ethical frameworks to integrate them into creative education is a significant challenge, which bears more attention, and should be the focus of future work in this area.

Ultimately, the goal is to foster a sense of identity among students as both learners and environmental stewards, emphasizing that the competencies developed through creative education should persist far beyond their formal schooling. This approach plays a pivotal role in learners’ participation in the sustainability movement, equipping them with the tools to navigate, influence, and contribute to a rapidly evolving world.

6. Conclusions

In this paper, we have emphasized the significance of intertwining creative pedagogies with sustainability principles, using AI as a lens through which to view the practical implications of this synthesis. The potential to prepare students to navigate, contribute to, and lead in a world that demands innovative, sustainable solutions is immense. This calls for a collective effort to further explore, implement, and refine educational approaches that harness the best of technology in service of a sustainable future.

The synthesis of creative pedagogies with sustainability principles presented in this paper uses artificial intelligence (AI) as a critical tool to explore and apply these concepts in education. AI, particularly through its capacity for data processing, pattern recognition, and generative capabilities, acts not just as a tool but as a lens. This “lens” allows for any range of possible functions as a cognitive tool that allows learners to do more, conceptually, than they could on their own (e.g., to simulate complex sustainability scenarios, generate diverse creative solutions, personalize learning experiences, engage critical data analysis, etc.). AI, in this paper, is a technological example for exploring the broader frame—which is the integration of creative pedagogy into a sustainability education frame. AI technologies enable educators and learners to visualize and engage with sustainability challenges in innovative ways, thus acting as a pivotal component in examining the practical implications of intertwining creative pedagogies with sustainability principles.

The intersection of AI, creative pedagogy, and sustainability education also opens up new avenues for research and practice. The conceptual model presented here may support future empirical research that could explore and expand on its propositions. One key area for such research might involve the effectiveness of creative pedagogies in enhancing understanding of sustainability concepts using AI, among diverse student populations. Future studies could investigate how creative pedagogies impact student engagement and learning outcomes in sustainability topics, potentially comparing the affordances of non-digital teaching methods with those of AI-enhanced approaches. Researchers might also explore more extended studies to assess the long-term impacts of creative sustainability education on students’ behaviors and attitudes towards the potentials and pitfalls of AI, providing deeper insights into how the proposed model affects sustainability actions, mindsets, and values. From a practical perspective, the integration of AI into sustainability education as outlined in our model implies significant advancements in educational practice and technology development. For developers, this calls for the creation of AI tools that are specifically designed to foster creativity and critical thinking within the context of
sustainability. This is an area that might greatly benefit from creative interdisciplinary collaborations. Fields like environmental science, cognitive psychology, computer science, and educational theory all have roles to play in providing key data and insights. Together with education experts, they might work to create AI systems that are not only technically proficient but also pedagogically sound and aligned with creative educational goals.

In practice, the model points to the need for professional development programs that not only provide training on using AI tools but also foster an understanding of how these technologies can be integrated into creative pedagogies that promote sustainability. Such programs should include components that encourage educators to experiment with AI in their teaching practices and to develop their own creative approaches to using technology in the classroom, stemming from the model’s principles. The implication is a shift towards more dynamic, interactive, and student-centered learning environments that effectively leverage technology to address global sustainability challenges. Moreover, it is crucial to address the ethical considerations of using AI in educational settings, ensuring that teachers are prepared to handle issues related to data privacy, bias in AI algorithms, and the digital divide. The framework presented in this paper is an initial exploration into a novel synthesis that integrates these notions of creative pedagogies and sustainability education, emphasizing technology like AI as a critical challenge. As a nascent contribution, it is intentionally theoretical, designed to spark further inquiry and development rather than provide exhaustive empirical validation or specific descriptions of particular tools (particularly since educational technology is a moving target and the landscape of this space is fast evolving). This approach allows us to outline broad principles and potential applications, setting the stage for future research to refine and expand upon this. By positioning the framework as a starting point, we invite a collaborative expansion and critical evaluation from academic and educational communities, encouraging the development of more detailed methodologies and possible practical implementation of AI-driven creative pedagogies in sustainability education.

The goal of bridging sustainability and creativity in education is about actively shaping a world where technology serves as a bridge to a sustainable and creatively vibrant future. Our synthesis does not simply suggest a model but envisions an educational paradigm—where action, mindset, and values are deeply interwoven with the essence of creativity and sustainability. This paradigm is set against the canvas of a digital age, where AI’s role is pivotal yet scrutinized, challenging us to rethink its integration in fostering environments conducive to holistic learning. This is both a challenge and an invitation to educators, learners, and stakeholders alike to redefine the purpose and practice of education in the 21st century.

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