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Deploying Generative AI and Cloud-Based Tools to Enhance Renewable Energy Education Platforms

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Abstract: Modern renewable energy education is being reshaped by the proliferation of generative AI technologies, cloud computing, and related tools. This paper investigates contemporary topics and trends regarding the intersection of these technologies and renewable energy area, focusing on education and research. Concepts are introduced and discussed continually, and the related challenges and technical concerns are framed around transparency, equity, saturation, validity, quality, and model sizes. The identified education and research themes in the field are listed and organized, and a survey grounded on them is compared with existing initiatives. A suite of systems and portals designed and constructed to address existing gaps is described. These executive systems are informed and guided by a series of questions regarding modes of engagement, expectations on results and generated outputs, and requirements regarding transparency and branding. The delivery mechanisms, both recurrent and ad-hoc during the academic lifecycle, are summarized. Cloud architecture, implementation details regarding popular APIs and generative design platforms, and applied Software Engineering guidelines are also presented, in order to ease the use of the discussed solutions and approaches, and help in the design, development, and implementation of new solutions. Notable academic projects and creative industries are also mentioned and reviewed, and future directions and projects are outlined, regarding the application of prompts, and the consideration of dependency on architecture exposed by recent publications on the topic.

Keywords: Generative AI, cloud-based tools, renewable energy education, digital learning platforms, AI-driven content creation, interactive simulations, real-time data analysis, personalized learning, smart grid education, machine learning, energy forecasting, remote labs, scalable infrastructure, virtual classrooms, adaptive learning systems, data visualization, educational technology, sustainable energy training, cloud computing, intelligent tutoring systems.

I. INTRODUCTION

The world faces increasingly urgent challenges in both climate and energy equity, which must be met with the rapid growth of renewable energy sources, providing everyday energy for all in a just and sustainable manner. A just energy transition must ensure that everyone feels ownership of its plans, policies, and projects. Exploring how energy works, with consideration of what makes energy accessible, acceptable and affordable for all, are crucial to realizing this. Yet there are few models present that will enthuse or inspire pupils to pursue this crucially needed work in their future, both in terms of careers and also in increasing electrification and circular economies that stop short future catastrophic climatic change. Generative AI, using immense and rapidly growing clouds of data, is developing rapidly and has shown how children, pupils and students around the world can feel excited by using its capabilities to their advantage, learning both how to interact with its answer, enhancing the usefulness of the output, and be re-inspired by using its pictures and images to trigger further questions about energy and climate systems and their interplay. Combining this with the digital cloud technologies available will not only make engaging pupils much easier but could also help enhance research efforts at several levels, thereby increasing the pace with which the new, urgently needed renewable energy technologies are invented, developed, deployed and utilized. This paper describes a research and educational effort currently being undertaken to develop means of using Generative AI and cloud technologies to enhance Renewable Energy Education for students at a range of ages, types and access levels. Expanding research capabilities and capacities at all levels of renewable energy work is critical to help rapidly transit to the impending energy transition, linking innovations from the modular scale for remote rural communities on renewable energy microgrids to islands and other regions with nuclear, solar and geothermal capacity linkages nearing necessary levels for 24/7 Propane free energy for sustainable economic development and recovery.

II. THE IMPORTANCE OF RENEWABLE ENERGY EDUCATION

Renewable energy sources have the potential to satisfy the global demand for energy end-use during this century, with a relative low environmental footprint compared to fossil fuel usage. The expansion of renewable energy technologies will

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require a mobilization of the best minds and the best talents and implies the need for a huge amount of engineers and decision makers. Teaching challenges vary from K-12 to university education and addressing them will require innovative solutions and the use of advanced technologies. Renewable energy education in K-12 promotes students interest in science and engineering, provides the scientific fundamentals to solution design during undergraduate studies, enhances the ethnic diversity of the energy sector which is crucial to balance the growing energy demand with a fair energy transition and secures the indirect support of future generations to renewable energy by creating a more informed citizenry. Renewable energy courses at the undergraduate level provide the necessary technical background in planetary boundaries, resource assessment and estimation of energy converters performance required to solve renewable energy design problems during the engineering capstone project course. A multidisciplinary set of elective courses offered throughout the undergraduate studies in engineering, the physical sciences, chemistry and applied mathematics increases the students capacities to explore the design space of renewable energy solutions needed to solve present and future energy-related problems.

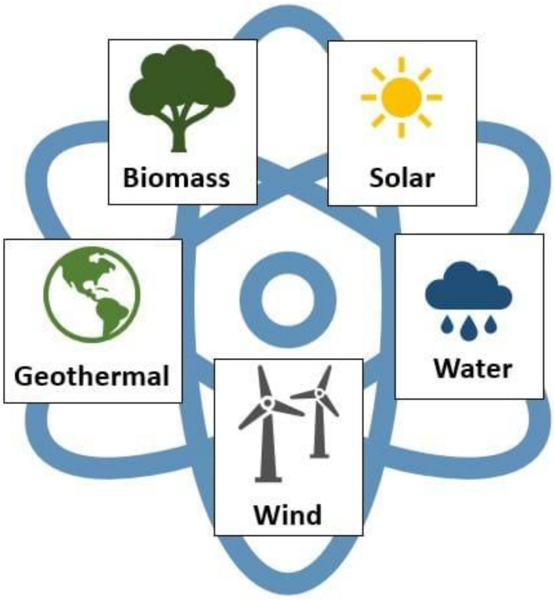

Fig 1: Renewable Energy - Lesson – Teach Engineering

III. OVERVIEW OF GENERATIVE AI

3.1. Definition and Concepts

Generative AI has gained significant attention over the past two years as it produces humanoid responses to user inquiries and commands, paving the way for mainstream adoption. Generative AI is defined as artificial intelligence that is capable of producing original content, often immersive or interactive experiences, including audio, code, images, text, simulations, 3D models, virtual agents, and videos, by using generative models and deep learning techniques. A distinctive design aspect of generative AI is its supportive role and collaborative power for the user, as it can serve content that closely captures the user's intent. GAI models include but are not limited to various applications. GAI technology spans several research disciplines, including computer vision, graphics rendering, multimedia, AI ethics, AI-human interaction, machine learning, and natural language processing and understanding. Generative neural networks, including Generative Adversarial Networks and Denoising Score Matching, are the building blocks of GAI. The most widely known GAI is the ChatGPT Large Language Model, which is a generative dialog agent trained on large sets of text data to conduct conversations with users. At its core, the GAI LLM infers sophisticated and relevant predictive models of text.

GAI has well-established applications in many aspects of modern life, including the movie industry, 3D scenery design, healthcare, marketing, news, communications, video game industry, computer graphics, art creation, programming, finance, automotive industry, and research. Just like any groundbreaking technology, GAI has raised numerous concerns, the most prominent being data privacy, AI bias, chatbots built with nefarious intent, copyright infringement, deep fakes which can enable a new generation of scams, fake news with richer audio-visual dimension, among others. More recently, GAI has sparked heated discussions about education integrity and the risks and opportunities of the use of generative tools.

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3.1. Definition and Concepts

The term "Generative Artificial Intelligence" refers to a conglomerate of technologies aimed at the production of content, be it text, photos, videos, sounds or computer programs. Currently, Generative AI has gained notoriety chiefly for its textual application, namely Large Language Models. LLMs allow the generation of fluid prose in natural language, spontaneously and just from a prompt. This kind of technology made this kind of technology popular and leveraged a vast ecosystem of competitors and collaborators to emerge around it.

Generative AI finds its roots in the evolution of a few key technologies, that are at its core. Firstly, basically all LLMs are Enhanced Transformer architectures. Originally proposed in 2017, Transformers have been the basis for many applications in Machine Learning. They have become the backbone for neural network architectures involved in Natural Language Processing, translated from one language to another, generated poems or essays, summarized large articles or documents, been used to build chatbots or perform language modeling tasks. The architecture is defined by a Sequence-to-Sequence Learning Model with Transformers. Sequence-to-Sequence Models are a powerful class of ML models initially proposed to handle Translation Tasks. They consist of two main components: An Encoder that maps an input sequence to a fixed-length representation and a Decoder that maps a code into an output sequence.

Eqn 1: Single-Diode Model Equation

$$I = I_{ph} - I_0\left(e^{\frac{q(V+IR_s)}{nkT}} - 1\right) - \frac{V + IR_s}{R_{sh}}$$

Where:

- I: Output current
- I_{ph}: Photogenerated current
- I_0: Reverse saturation current
- V: Terminal voltage
- R_s, R_{sh}: Series and shunt resistance
- n: Ideality factor
- q: Charge of an electron
- k: Boltzmann constant
- T: Temperature (K)

3.2. Applications in Education

Generative AI holds incredible potential to assist and enhance human creativity across multiple disciplines, effectively liberating humans from mundane tasks and stimulating more engaging and productive activities. Notably, for educational environments, the integration of Generative AI into daily practice has been proposed in many fields and matters, including business, medicine, technology, law, language, social sciences, and the arts. In particular, LLMs have shown enhanced potential for natural language-supported activities, such as written production, review, and critique, foreign language teaching, linguistic and syntactic support, interviews and exploration of historical and contemporary events, and even argument formulation. Nevertheless, such tools are not without their limitations. Accordingly, while recognizing and listing the direction, usage, and potential, we must note that the same limitations prevailing in all Generative AI systems still apply in educational activities.

As an emerging and trending technology, Generative AI is a catalyst for extensive and necessary changes in educational contexts. The first level of technology integration is a simple tool that improves or enhances current activities but does not change established methods or approaches. Currently, such a level is reached when students use Generative AI to generate drafts, outlines, or plans of their works, benefiting from immediate and free editing, design, and graphical illustration support. However, this scenario raises concerns regarding responsibility and provides opportunities for deception, themed “cheating”. Indeed, it is quite simple to generate a high-level quality text using AI tools and submit it, but this practice detracts from the motivation and learning opportunities designed and followed by educators.

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To overcome such a dilemma, we should strive for the second level of integration, in which Generative AI positively affects the planned outcomes and the related process positively. This might include co-authoring Generative AI as part of students' (and teachers') creative activities.

IV. CLOUD-BASED TOOLS IN EDUCATION

Cloud computing is rapidly changing how the education process works by creating a virtual ecosystem that allows schools to remove the physical barriers that can inhibit information sharing and free up resources to invest in educational tools. Instead of keeping physical towers in a computer room, cloud computing extends networked storage and processing power to any authorized user who has access to the internet. Cloud computing enables virtual computing solutions such as storage, games, networks, processed documents, and more to be accessed anytime, anywhere. However, the fast distribution of a large number of tools belonging to the cloud environment is minimizing the difference between physical and cyberspace surrounding students and teachers. New applications make life easier for students and teachers alike, as they allow for connecting and collaborating on assignments and discussion groups, and even allow teachers to organize their classes.

Today, students can use their days at school as studios, galleries, recording studios, or movie sets. It is possible to make real magic with the wide array of web-based tools that are available. Certainly, the free applications that are available today provide creation and sharing capabilities that hardly existed a few years back. The fact that tools are either free or extremely inexpensive makes them even more attractive for teachers. Additionally, many of them can be integrated into a Learning Management System and/or used on mobile devices. Indeed, the explosion of mobile technology is such that it is not uncommon to see students in schools who use them for their assignments and projects. These cloud tools include various presentation tools, screencasting tools, video creation tools, photo and document sharing tools, music sharing tools, blog hosting tools, live chat tools, and survey tools. These tools can be shared via multiple sites and can help students worldwide work on a simple project.

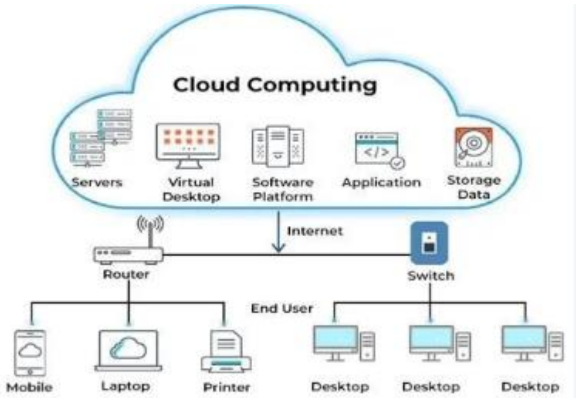

Fig 2: Cloud Computing Revolutionizing Education and Learning

4.1. Benefits of Cloud Computing

Cloud computing connective devices are now an integral element of technological advance. Cloud-based applicatory programs present advantages ranging from simplified organization of files and resources, to easy access from virtually any computer connected to the Internet, and the ability to easily share files with others. However, while tools that exploit cloud technology are being used on a massive scale by millions of people every day, educators have only begun to explore the ways in which cloud-based technology can be used to enhance their courses and the learning experience. Courses which integrate cloud-based tools into their activities present an innovative and interactive change from the traditional college course model that occurs, for better or worse, as a product of lecture, textbooks, and exams. By taking advantage of cloud technology, educators are able to shift the focus of their course from standardized testing of what is supposed to be learned, to collaborative, active learning processes that develop conceptual understanding. By encouraging formations of groups of students in different locations and time zones, the cloud removes the physical and temporal constraints that have historically made collaborative online learning difficult.

Along with the new opportunities that reside within these tools await new responsibilities for the educator. As cloud-based environments facilitate group work and collaborations that can last across the whole length of a course, they also require educators to aid students in the process of group formation, management and interpersonal analysis; skills that many students have had little or no experience with in the past.

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To successfully integrate cloud-based tools into a course, the educator is charged with guiding the student through the process, in structured environments that ultimately develop the student's abilities to effectively help one another in meaningful ways throughout the course and after their formal education. With the abundance of free tools available based on cloud technology, both students and educators can easily take advantage of their capabilities to enhance the traditional learning experience.

4.2. Popular Cloud Tools for Education

This section reports and discusses some of the popular tools inspired by the previous, heuristic reflections. For instance, a big suite of utilities can be accessed by any user, including teachers. Popular services like Drive, Docs, Slides, and email among others allow teachers and students to build their activities and collaborate on educational projects. Cloud services enable quick and easy access to many essential collaborative tools. Similarly, Editor, Sway, Teams, OneDrive, and Office365 offer an array of features appealing to teaching and learning processes.

Supporting Communication activities, Edmodo, WordPress, Weebly, Articulate, and Wix may be inserted in the list. Platforms for Learning Management like Edmodo, Schoology, Classroom, Talent LMS, and Canvas are particularly dedicated to managing course materials, classroom collaboration, assessments, or even cloud-based educational delivery for online courses, and making the student-teacher relation more flexible, fluid, and effective. Furthermore, among the Cloud Constructivist tools, can be considered, associated with the Field of Interest Coding and Game Design, while Genially, Kive, Canva, PowerPoint, and Prezi may be referred to as Cloud Creative Presentation helpers in the Digital Storytelling area.

Concerning the CAC in Language Teaching, should be mentioned in the Business Field. Moreover, for the Cloud SPS tools: Forms, and would also work both for Online Coding and Business courses, but also for university-level Language courses. The last comment should be dedicated to the previous mentioned Resources Sharing category. are indeed essential Resources Sharing-Educative and Open platforms being used in almost every Field of Interest.

V. INTEGRATING GENERATIVE AI IN RENEWABLE ENERGY EDUCATION

We discuss two different levels of use of Generative AI tools in renewable energy education to develop skills, boost up interest and increase retention of students in the use of renewable energy sources. The first function is to use these tools in the creation of renewable energy focused educational material, either to update or develop a new curriculum or to generate new or enhancing online classes. Generative AI has the capability to generate new innovative ideas for any given topic, its enablement with plugins or custom tools to help to translate this information into new or enhance traditional renewable energy sources can help instructors focus on new developments in this area but make the actual development of the material easier for them. Some advantages of the Generative AI use on this level are potential faster generation of educational material; quick access to information, innovative ideas, and updated information based on recent information; and automatic translations to other languages. Some disadvantages are the possible inaccuracies produced by the Generative AI tools in the material generated and the lack of computer-accessible structure for the generated content or potential bias based on the instructions provided to the tool.

Eqn 2 : Wind Power Output Equation

$$P_{wind} = \frac{1}{2}\rho A C_p v^3$$

Where:

- ρ: Air density
- A: Rotor swept area
- C_p: Power coefficient
- v: Wind speed

The second way of use is to enhance the learning experience of students, by using the Generative AI tools for material review or brainstorm sessions or for instant doubt resolution. In the current educational landscape, Generative AI can help ask very specific questions to assist the student in understanding any topic when asked specific questions.

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Generative AI can enhance the student experience during laboratory work as well, helping with equipment that can be overwhelming or intimidating.

5.1. Curriculum Development

This section explores potential course materials, assignments, and the major components for an advanced course in renewable energy curriculum that use generative AI. Similar to the introduction lecture that describes generative AI and its capabilities, example assignments are also included for each topic. These assignments are meant to be templates to allow for flexibility in course development and implementation; educators are free to modify or improve them. Some of the course materials are language prompts explicitly designed to return educational material. They are intended for use by an educator as a teaching assistant who may perform minor modifications or improvements to the content. While these assignments are designed for use by a higher education audience taking a full-time academic course, they could also be adapted for workplace training with moderate amounts of modification and personalization. Teaching an advanced course on renewable energy use in the context of recent decisions regarding the Clean Power Plan and the upcoming release of the Seventh Assessment Report of the Intergovernmental Panel on Climate Change would allow for incorporation of concurrently released science updates for incorporation within courses. Making this connection allows the entire course and each of its components to be up to date with the latest climate research as well as policy news. The use of generative AI tools have the potential to significantly shorten student turnaround time as well as ease the educator's development time, allowing for more efficient research and learning outcomes. Given that climate will affect all future generations, introducing generative AI to the renewable energy curriculum allows students the opportunity to have both an up-to-date and personalized AI-generated research experience. Generative AI should be an integral part of any future-oriented syllabus.

5.2. Interactive Learning Experiences

The creation of interactive didactic modules that can deliver unique learning experiences demands the integration of different technologies. This is the case of virtual and augmented reality that allow building immersive worlds where the user can interact with 3D models while the motion is being tracked. These types of experiences enhance the creativity of students and are very engaging. However, the creation of custom content that adapts to the course and specific needs of the students is not trivial and requires specialized knowledge. Besides, they need a powerful computer to run their solutions to make an engaging interactive experience. Also, in some cases, students need high-performance equipment for playing and experiencing the immersive content. On the other hand, generative agents can provide some of the customization capabilities that require technical expertise. Users can leverage an intelligent interface created by an artificial intelligence agent that allows users to specify topics, answer questions as experts in specific areas, and adapt the agent’s behavior to the topic being studied. The AI agent can present its customized virtual character to promote engagement and immersion, but also, thanks to its natural conversational interface, provide dynamic and personalized responses.

Fig 3: 10 types interactive content

Within this context, a team of professors created a non-immersive interactive experience and a complete immersive experience built with advanced mixed-immersive reality technology that are hosted in a cloud environment. These experiences can be fully customized using generative artificial intelligence technology facilitated by generative conversational agents integrated into the virtual world in the case of the non-immersive experience or launched into different rooms of the immersive space in the case of the immersive world.

VI. CASE STUDIES OF SUCCESSFUL IMPLEMENTATIONS

This section presents some case studies of courses and programs at universities in different regions of the globe where tools and concepts of generative AI are being applied to enhance the education of renewable energy systems.

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These real-world implementations may serve as models for the fresh sustainability efforts of educators around the world who are willing to collaborate to enhance our students' and future professionals' knowledge of sustainable technologies and systems used to fight climate change. These collaborations as networks of institutions leveraging IT tools and technologies for collaboration of reduced to zero costs should ultimately coalesce into a transdisciplinary sustainable knowledge hub that will deepen our understanding of the complex climate and societal challenges we are facing. The combination of sustainability principles, the tools of generative AI, ethically fostered collaborations using modern online education principles, and the cloud technologies that make this possible could lead to a new generation of professionals and thinkers capable of addressing these complex societal challenges. This section shows some of these early case studies collected through a literature review and a search on online platforms. Neither the time nor space limitations allow the authors to develop deeply each of the cases described here. The intention is to provide credible references to further explore each of them. This may be the basis to subsequently plan collaborative programs at larger scales among different institutions and regions of experts and professional educators.

6.1. University Programs

Over the last years, globally, higher education institutions have focused on interdisciplinary approaches in curriculum design. For example, one institution promotes the increasing importance of sustainability in various curricula, highlighting global change issues over disciplinary boundaries, while another restructured its graduate program in climate sciences as a response to the impacts of climate change. Transdisciplinarity and comprehensive education that merges specialized education with the formation of ethical and responsible professionals are also promoted by another institution. Furthermore, to attend the needed transition from a fossil-fuel-powered system to a sustainable development scenario dependent on the extensive incorporation of renewable energy technologies, researchers argue that education is essential to prepare future leaders in the new energy economy.

Various organizations promote the establishment of academic networks that have the goal of improving access to quality education in energy, forming competent professionals for the energy transition. The creation of programs that focus on the transition toward clean energy is also recommended by another organization. These organizations recognize that partnerships between public and private sectors and the cooperation between countries developing renewable energy technologies and the others that are implementing them or still have to do it are essential to achieve these goals. However, to fulfill these identified needs, it is essential to improve current programs in energy engineering and technology and other related programs and to create new innovative programs that will improve the qualifications of engineers and prepare them for the energy transition.

6.2. Online Learning Platforms

Many online programs offer courses related to renewable energy at various levels given their topical versatility. Some of these programs include various providers who can present high quality MOOCs for the developers interested in this field of knowledge. Originally, some online courses were confined to a classroom environment synchronous, with the course resources available online in the provider's platform. However, the budgetary constraints faced by universities and colleges in recent years have compelled some to offer joint MOOCS in order to share social and technical costs. MOOCs have become a successful approach to long-distance education. Even before MOOCs reached a large audience, there were popular long-distance courses that filled the gap between education and training.

Nonetheless, online platforms are mostly known by extending E-Learning to self-paced training experiences. Following the model set by various platforms, it is argued that other than inside-organization training, as offered by companies, there are two pathways for online learning today. The first is that followed by the companies behind such E-Learning platforms. Each provides a series of online courses attracting learners to its platform or to university or company partnerships, and certification and micro-credentials are optional. The second pathway blends formal education with largely self-paced training experiences, taking the form of Guided Learning Pathways or Micro-Bachelor programs.

Eqn 3 : Equation (Bayesian Knowledge Tracing - BKT

$$P(L_t) = P(L_{t-1}) \cdot (1 - S) + (1 - P(L_{t-1})) \cdot T$$

Where:

- $P(L_t)$: Probability that the learner knows a skill at time t
- S: Slip probability (student knows but answers incorrectly)
- T: Transition probability (learning after an attempt)
- BKT is used to track learning over time and adjust questions accordingly

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On the other hand, E-Learning is found primarily on long-distance university programs and used more often than not to complement traditional higher education, which helped to popularize it over the years. Various administrators from universities around the world have attempted to integrate a series of top E-Learning courses to create a joint platform.

VII. CHALLENGES AND LIMITATIONS

As the previous sections show, augmented, remote and cloud-enabled generative AI educational tools are particularly useful, benefiting students and teachers alike. However, such tools are not without their disadvantages. There are important technical barriers to be overcome before these tools can be widely adopted and employed. Furthermore, equitable access to the necessary technology is a growing concern, especially in the Global South, where financial, socio-cultural and infrastructural elements make adopting and employing technological advancements difficult. The following sections discuss these issues in greater detail.

Several technical challenges affect the reliable operation of AR, cloud and generative AI tools in education. System failures and incorrect responses can be distracting, frustrating and deter rather than facilitate learning, while tutor fatigue may occur when a tutor is bombarded with questions. Furthermore, providing service to large amounts of incoming requests and delivering timely responses requires considerable resources, and blurry, unrealistic and incorrect rendering or recognition can also distract students. In addition, students often struggle with understanding emergent and counter-intuitive behavior, particularly in the case of non-human-like or otherwise exceptional tools unable to invoke fellow feelings. These barriers make researching and developing educational tools employing the emerging technologies especially important.

The implementation of educational technologies is an emerging concern, especially in the Global South, where low uptake of distance learning consultancy has been observed. The growth of the knowledge economy has increased the global research and development expenditure, with two-thirds of the world's researchers located in just 11 countries. Nearly half of worldwide scientific research output is published by researchers from a few countries alone – a trend that is also visible in renewables and climate mitigation. Such disparities are worrying. Increasing concerns relate to educational equity, given these disparities. We argue that a fellowship type solution is needed, with more focus on low-income, vulnerable and underserved organizations, institutions and individuals.

7.1. Technical Barriers

Cloud-based tools reduce the technical barriers to successfully evaluate renewable energy technologies. However, there remains a wealth of additional technical details that would make evaluating the technology's impact easier. Generative AI enables a virtual assistant of sorts, far exceeding existing chat-based AI, so that large portions of this tedious technical work can be conducted at an advanced, research level. However, there is still a need for this lower-barrier collaborative work, and not everyone will have access to the higher accuracy AI. Further, the learning that will be lost as prep work and difficult coding is absorbed by AI is present in existing cloud tools, which should serve as a stop-gap measure. When a new curriculum is being developed, inexpensive models may break down or serve entire classrooms with little monitoring. Using guided working examples and annotations may strengthen or weaken the learning opportunity. Thus, it is very possible that future students will not have access to these powerful tools and the guidance will allow a faculty instructor to track student understanding better.

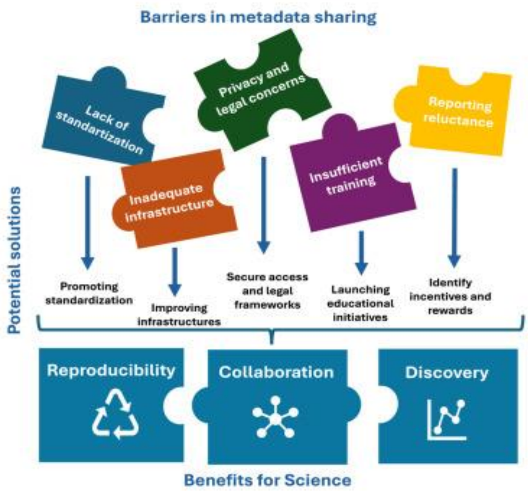

Fig 4 : Perceptual and technical barriers in sharing and formatting metadata accompanying omics studies

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Several data sets available on the functioning of renewable energy technologies may become integrated into these systems to populate or check the models' predictions. However, these data sets may simply be poorly aggregated – a small portion of these data sets can be used to tune and correct AI model outputs, or entirely new, present-day monitored data-only predictive tools can be created. Faculty should be data stewards, collecting data from existing projects and integrating them with those being used to calibrate developing predictive models. Data availability policies should accompany these model releases and allow students to experience the full predictive modeling process. Further, cloud resources can facilitate students' access to the tools.

7.2. Educational Equity

No single aspect of the energy transition is more pressing and non-delegable than equity. It is our capacity to make the transition a pillar of inclusion; as such, it ensures that the ET does not recreate new inequities and affirms its role as an effective vector of justice. Countries must invest additional resources in education, skills development, and technology transfer and create opportunities that allow everybody to participate in and benefit from the transition. In this context, the role of educational systems becomes crucial, and embedding energy transition content into curricula, especially at school level, is key. To do so successfully, however, educational systems must first ensure that access to quality education and learning experiences is equitable.

In fact, while other sectors have created the enabling frameworks for a low-carbon transition, primary responsibility for safeguarding equitable access to the transition rests with education. This requires both demand-side and supply-side interventions: on the one hand, it entails curating skills development pathways for the most disadvantaged—youth, women, dropouts—that help them find jobs in the transition; on the other hand, it requires that the treatment of disadvantaged communities in consultations or negotiations in the course of the transition design, implementation, and impact assessments process be equitable and offer equal voice to all, regardless of gender, age, political affiliation, education status, or health. If they are not guiding principles for transition-building and if accountability mechanisms are not put in place to ensure that equity and inclusiveness principles are adhered to and implemented, it will be impossible for education systems to reinforce the equity pillars of the transition.

VIII. FUTURE TRENDS IN RENEWABLE ENERGY EDUCATION

As new technological advancements and societal challenges arise, the education landscape is adjusting to provide the lessons necessary to cope with future difficulties. With each successive leap in technological capabilities, economies have shifted, along with the needs for skilled labor to provide the best possible solution to the economy at hand. While the most recent developments in renewable energy education have been centered around the needs of both the industry and society alike, new advancements in technology are poised to further disrupt the work done today. Along with these shifts come the need for more informed and specialized workers, particularly in the field of STEM education, encompassing both a strong technical foundation and the skills to develop more innovative approaches. Education in these areas will need to adapt based on the societal needs and the advancements made through research in order to ensure success for future generations.

Fig 5: The Future of Energy: Exploring Trends in Renewable Sources

Positive Affordances associated with Generative AI offer novel learning experiences for students and more efficient operations for academic institutions. We expect these emerging technologies will enable exciting developments in the future of higher education, and specifically how generative AI technology services accessible via the Cloud will transform renewable energy education to incorporate intelligent tutoring, personalized and adaptive learning, creating virtual teaching assistants, automating grading with explainable AI, knowledge augmentation, non-player characters, and ethical aspects of generative AI.

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No technology is without blame, and while it opens up exciting new possibilities, generative AI in its current nonsupervised form can add to educational disparities among institutions that can afford tools and those that cannot, and also adds to preexisting concerns around academic integrity with students using the technology for plagiarism and the result of students losing vital skills development.

8.1. Advancements in AI Technology

Recent years have witnessed significant advances in artificial intelligence technology, such as transforming the way we create and consume digital content. Large language models generate humanlike written text and image synthesis models are able to create startlingly realistic images based on voice prompts, have advanced to a degree that many students are already using them to complete college assignments. While many traditional computer vision, natural language processing, and speech recognition tasks have been automated for some time, recent state-of-the-art language and vision models are redefining more complex tasks, such as creative writing, content editing, or data analytics workflows, traditionally associated with cognitive human expertise. The advent of advancements in generative AI, capable of generating complex digital content, transforms the qualitative precision of what machines can do and will increasingly redefine what socio-technical problems they are better placed to solve than human workers.

Generative AI seamlessly blends digital content creation, which was traditionally more human-centered, with automation, but it is already blending it with the physical world. It has done so by rapidly merging with robotics, while also allowing physical robots to generate the articulations of their moves while they weld or the diagnostics of what they are inspecting in an assembly line. Generative artificial intelligence is growing up to be a general-purpose technology of knowledge-intensive production and services because it was considering the fact that it would not simply automate mind-work but will offer tools for collaboration with mind-workers. Generative AI is automating parts of complex and artistic tasks such as the large-scale production of original music, the generation of highly realistic textures for 3D animation, and video editing, thus opening new frontiers of possibilities for what human creativity might accomplish in interaction with machines.

8.2. Evolving Educational Needs

It is widely recognized that further integration of renewable energy into various sectors of society, coupled with the growing global energy demand, is becoming critical and urgent. Aided by digitalization technologies, the process of enhancing renewable energy deployment is underway in many sectors including buildings, industry, mobility, and power systems, while also facilitating applications in areas such as grids, markets, and climate change. Progressing into the next decades, new developments in multiple areas will generate a range of new job roles and complimentary skills that will emerge and impact the sectors across the renewable energy economy. These skills do not only apply to the renewable energy and power system domains, but also reach into the intersections of those sectors with buildings, industry, mobility, financial markets, and climate change. With cities and communities becoming critical stakeholders driving the transition of decarbonisation, energy structural change, and climate adaptation, the demand for new skills will also be requested by local governments.

As such, and in parallel to the existing routes along degrees and traditional preliminary educations in the various fields related to renewable energy, there is an urgent need for upskilling and reskilling across the board and for new collaborations with enrollment driven by the industrial and technology sectors. The existing workforce under-invested in digital skills will need focused support from educational entrepreneurs, providers, and practitioners, such as short-term boot camps, on-the-job-training, and bridge courses that are recognised by industry and work-based learning experienced coordinators. In particular, specific attention will need to be dedicated to those sensitive groups in need of second chances who may require assisted support but have the desire, motivation, and capability to be educated and reskilled. In addressing this gap, the role of technology plays a fundamental role in enabling these new educational needs and supporting employees in their capacity development.

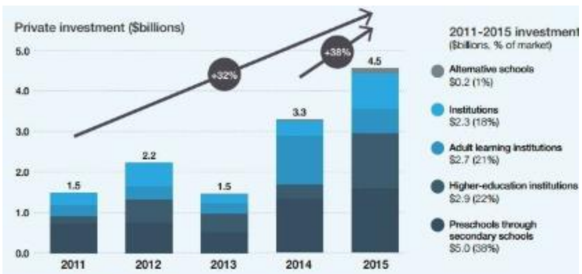

Fig: future of education

IX. POLICY IMPLICATIONS

New educational technologies have drawn the attention of education policy generally, and energy economics education policy in particular. However, federal regulations may limit the implementation of various educational technologies. At a minimum, the educational impact of regulations is likely to be difficult to measure and uneven in effectiveness. As a result, the pre-existing regulatory frameworks should be supplemented with additional provisions that explicitly consider technology development. Currently, there are significant opportunities that lead to an uneven field that can distort the intended outcomes of these regulations. Advanced software platforms for developing and hosting advanced technology implemented educational modules should be explicitly given special funding and additional points in related funding and project selection processes as long as their use on specifically specified projects is technically feasible.

In terms of support, the rules for maximizing the effectiveness of these policy levers should be viewed in conjunction with each other. This means that support in appropriate areas can be justified in order to enhance the educational impact of funding for specific projects, and limitations on funding should be taken to promote these effects rather than for the usual purposes of policy funding; this should apply to specific novel educational technology projects that enhance understanding among any initially specified audience. While various educational tools have been developed and various certifications for using them made available, these should be viewed as starting points. The dynamic capabilities of economic development are supposed to built-up over time along with the accomplishments of the individuals involved, rather than being one-time experiences.

9.1. Regulatory Considerations

Generative AI and cloud technologies could provide an entirely new approach and paradigm to renewable energy education, creating a dynamically vibrant and constantly updated resource. This chapter summarizes our findings and presents some policy recommendations for consideration by governments, institutions, and regulators around the world. The growth of Generative AI presents a challenge and an opportunity for regulatory bodies. The challenge relates to the speed at which these systems are advancing. It will be important to keep up with the advances in these technologies in terms of understanding what is possible, what is desirable, and what might be harmful. For those with AI oversight responsibilities, the ability to interact meaningfully and effectively with these systems – asking questions and getting practical and useful responses – is vital to being able to respond appropriately. Unfortunately, for many government bodies and organizations, the development of AI literacy has not kept up with the pace of development in the underlying technologies and this is likely to continue for some time. The opportunity is to become familiar with these systems and think about what regulations might be useful in terms of making the most of these systems.

In this context, the emphasis of regulators at this stage should be on understanding and facilitating the further development of Generative AI as opposed to trying to stop it or constrain it. In this regard, there are a number of suggestions that have emerged from our work in this area. First, it is important to ensure easy access to high-quality large language models for experimentation. This could involve funding the release of new datasets but also supporting large language models that prioritize open access and responsible development.

9.2. Funding and Support

Before any new technology can be rolled out on a large scale, issues such as national policy priorities, stakeholder interactions and financial support must be addressed. Given that the initial incorporation of AI will have a higher barrier to threshold, it will be required to have temporary budgets to incorporate this new tool. With time, once implementation is done nationwide, resource demands can go back to current levels. In this light, international donors or funds can provide temporary funding to bolster upfront costs of deploying the Generative AI technology. Theory of change considerations also highlight interdependencies between the technology innovation support and achievement of stakeholder engagement objectives and capacity building in-country.

The global understanding of the transition to a greener economy and low-emission methods of production has gained momentum, and donors and multilaterals have transformed their portfolios and programs into a greener perspective. Indonesia's acid test is how to mainstream digital enablers such as GenAI in the process of decarbonization of the industrial sectors. The specific economic scale is a very important point to support this optimistic vision as GenAI in various sectors can give clear results in the short term, namely actual impact for corporations and business actors in doing a green movement that's more than just a wishful idea, somehow. The funding also needs to be in parallel with education and training programs or mentorship, so that ways to accelerate would become clearer, thus promoting the idea of decarbonization not as an obligation, but as a must.

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X. COLLABORATIVE EFFORTS IN EDUCATION

While content creation is becoming more and more accessible, the educational system itself suffers from a lack of effective hands-on resources and practices to help instructors. What is needed now is a collaboration between different institutions that will make available reliable material and joint initiatives to train instructors and collaborators, filling this gap. This chapter exposes the importance of collaborative efforts in higher education to leverage new technologies and offers examples of efforts made by various institutions in partnership with industry leaders as well as other international initiatives to shape the future of education.

Industry partners help universities create up-to-date training programs that work in tandem with their technology and have ample research opportunities for students and professors. Leaders in artificial intelligence allow students and professors to access research tools and take research topic courses. A branch of industry research works hand in hand with universities to develop training programs, especially for instructors. Educators help institutions create step-by-step courses that fit their needs and help deliver those programs, creating know-how and increasing instructor confidence. These course materials are certified, which greatly increases industry demand for those who take them. But the initiative goes a step further by creating a train-the-trainer program, which personally trains some instructors to deliver these programs down to get community certification. Students passing the courses are both certified and get tutor experience during those programs.

10.1. Partnerships with Industry

The majority of research and development (R&D) in new renewable energy sources and techniques happens at companies and specialized research institutes. College and university faculty members and students are typically not engaged in this effort. There are already many firms producing the hardware needed to generate solar, wind, tidal, and other renewable power. There is a need for closer collaboration between research in academia and development in industry. Faculty members in engineering and science departments at many colleges and universities are already involved in work at summer jobs, during leaves of absence, and even on a full-time basis. Sharing ideas and resources in all directions will enhance research, development, and implementation of renewable energy sources and techniques. Industry partners help to keep technical information current, provide ideas for projects, sponsor co-op students and interns, and bring a larger talent pool to the interview sessions when considering full-time hires. Many companies are examining alternative energy strategies to minimize production costs while contributing to an enhanced image as “green corporations.” Reducing costs for R&D while speeding up the pace at which ideas move into commercial availability can often be achieved through collaboration with a university or research institution. Partnership projects and joint ventures are becoming more common. With the availability of new digital technologies, and especially machine learning and AI-based data analytics, the activities associated with R&D can be greatly reduced. This discussion further explores how close collaboration between industry and academia will benefit both.

10.2. Global Educational Initiatives

The aim of enhancing renewable energy education is a universally recognized social need that is considered as one of the key objectives of the renewable energy community group, which is focused on providing a set of coordinated, growing and global efforts for the creation, dissemination and evidence of effective educational experiences based on renewables. This paper summarizes efforts in the community in terms of a knowledge hub for renewable energy education that is complemented by sessions. These sessions are used for the presentation of new evidence, new fashionable themes and/or benchmark experiences that have served to promote novel renewable education topics or that present collaborative experiences or target at establishing partners with towns. For these specific purposes, sessions are preferred as a means to deliver lessons learned camouflaged behind a dialogue-based informal session.

XI. ASSESSMENT AND EVALUATION METHODS

Learning analytics supports meaningful discussions around assessment from multiple perspectives. For example, assessment relates to the overall academic performance of a student, but it can also denote whether an individual student found a certain course stimulating or if it contributed significantly to their education. Expressed in terms of learning analytics, other key metrics besides academic success include overall evaluation effort, number of assignments submitted relative to number of assignments available, time spent on evaluation-related activities relative to total time spent in the course, and multiple-choice-test answer correlation.

Academic success is primarily evaluated through exam and assignment grades. In practice, these numbers are fragmented throughout several assessments, with different students allocated to each test sitting, potentially creating significant variations due to small groups of students.

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The semester average is computed through a weighted average of all individual event grades, taking the standard course weighting into account. Due to drastic differences in the degree of automation of different formats, the contribution of a given assessment has been normalized to a maximum of 30% of the course grading. The remaining course evaluation weight is assigned to on-site tests, especially in the computing disciplines. The method used for grading multiple-choice tests relies on a formula that penalizes guessing. Using the learning analytics, we display a comparison of a participant's multiple-choice test answers with those of the group. Additionally, we define weak predictors as poorly performing students for which the group's output differs greatly from the output of the successful student's.

11.1. Measuring Learning Outcomes

This work recognizes that online courses and programs can typically feature a dizzying variety of learning assessment mechanisms, from objective quizzes to portfolio entries. Accordingly, they highlight the fact that learning outcomes should thus be custom-designed for the specific course they are assessing, to accomplish the tasks set out in our previous section. The authors have attempted to show the available tools for creating custom learning assessment systems suited for specific course and program objectives at various types of educational programs. They assess traditional educational learning assessment items such as objective-style quizzes. They do find unit-specific quizzes to be effective in traditional educational collaborations. In online course settings focusing on older, adult students, they find the unit quiz item less effective. They assess more subjective assessments such as discussion posts and final project essays to positive effect in a course setting which offers older adults title experience. They propose capping off educational experiences with completion certificates earned through rigorous project outputs which conform to employer standards, giving students a strong signal of their proficiency or readiness. Finally, with courses offering continued education, they opine employers are the best source of identified skill gaps which education programs can address through assessments, abstracted outward from the educational program. The authors present a collection of the items described above for use as course taxonomy keys.

11.2. Feedback Mechanisms

Frequential or continuous course feedback is considered a good practice in higher education. There are multiple benefits of offering feedback during the course. First, formative feedback allows students to customize their educational experience as it is still possible to influence the results and adapt learning approaches according to the feedback, for example, repetitively formulate and refine learning outcomes. Second, it encourages the students to stay engaged throughout the whole course instead of investing their efforts only in exam preparation. Third, continuous feedback serves as a quality "thermometer" for the teachers, showing if they have succeeded in transferring the knowledge and skills needed. And finally, this approach also allows them to modify and improve their teaching methods during a course if needed, allowing for reuse principles.

Feedback can take many forms but is usually complemented with follow-up workshops, coaching sessions, or feedback conversations. It is usually difficult for teachers to provide qualitative personalized feedback to a big number of students. Generative models can be used for semi-automatically generating this feedback, thus helping both students in their educational journey and teachers to lessen their workload. These models can be used for text or programming reviews, for example, to assess students' responses, point out flaws, critique the ideas presented, or offer possible improvements. Due to its coding-specific fine-tuning, the model can provide a comprehensive review of the coding task that is prompt-engineering aware and helpful. However, teachers should be aware of the consequences of imperfections such as politeness, over-explanation, and similar considerations while using AI-generated personalized feedback for the students.

XII. BEST PRACTICES FOR IMPLEMENTATION

Properly implementing new tools for teaching helps maximize the chances those tools will enhance teaching and learning. In particular, two areas seem particularly important: training educators and engaging students. Our work shows that ease of access is not enough to ensure that tools are used appropriately. Educators want to understand the technical aspects, advantages, and limitations of novel tools, and they need to create assignments that effectively harness those tools. Preliminary results from using similar tools in the chemistry classroom indicate that students are likely to be enamored with the novelty of the tools at first, but if they do not realize why they are using them, they are unlikely to use them deeply or meaningfully. We hope to share examples of assignments in the future that have been refined using these suggestions.

Educators must be trained in both the technical aspects of a tool's most powerful features as well as in the pedagogical ideas of alignment and meaningful use. Educators who know how to best use a tool may be energized by the idea of implementing it in the classroom and may create assignments that encourage careful consideration of the prompts, intended function, expected product, and thought process leading to the use of the tool.

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Workshops or meetings bringing together faculty from different departments who use similar tools may allow for cross-pollination of techniques and assignment ideas and help educators quickly overcome technical hurdles.
Even with thoughtful assignment design, students may struggle to see the value in the use of a tool. It has been observed that students are often drawn to task completion by the novelty of the tool, and if they do not consider the goal or significance of the assignment, they may complete it in a surface-level way without any motivation for deeper thought. Transparent assignment design, including open discussions around the intent of the assignment, is essential to overcoming the mindset of pandering to the tool.

12.1. Training Educators

Generative AI is transforming education in renewable energy (RE), bringing unprecedented opportunities to clarify complex concepts, synthesize detailed course outlines and lesson plans in minutes, visualize complex relations using illustrations, pictures, video or animations, generate quizzes, study guides, homework exercises and examples in seconds, and draft detailed reports and search the latest scientific literature. No more tedious tasks of preparing visual slides for each lesson or having to proofread archaeologically built-up slides for each presentation from multiple sources over many years for minor text style and image-size interference. However, this treasure trove of opportunities will only work if RE educators are trained to use Generative AI at its fullest.

The first step, which is already happening, is introducing Generative AI enabled tools and services as an additional part of the access to tools required by the ABET accreditation. Although students are ready, educators will need training to be prepared to integrate Generative AI into their lectures, exercise problems, exams, labs, and projects. It is certain that we will use Generative AIs in that process but how to enroll training of all most college faculty members remains an open issue. How do we make them aware that GenAI is more than a chatbot allowing to pass college courses? The answer may be developing experiential workshops to be proposed by progressively more faculty members. Educators will be engaged applying all these tools to RE difficult topics, working on tools and content recommendation systems, answering, critiquing, and building Generative AIs for high quality education in RE topics before Generation AIs become regular educative tools used by RE professors and students at all levels.

12.2. Engaging Students

A major problem with education around climate change and renewable energies is the fact that students do not find it interesting enough. Some students may think that these topics and its resultant work are boring. Many students have never questioned where the sources of energy come from. They are not aware how much effort and ingenuity has been needed, among many countries, to specialize in designing new sources, different from the old, polluting fossil fuels. Technology has advanced enormously in the last decades in order to make new technologies more efficient and cheaper; and these are the technologies students should learn about. They should wonder about how these devices work and how they have been optimized; or how they will evolve into the next versions: better, more efficient and cheap. Innovations require trained people to create the new devices the world is in need. Students must realize that once they get their degrees they will be capable of designing and building better solutions. The way in which a teacher approaches these topics, the material used, the ambiance of the classroom turns this subject into something really exciting or really boring. Students must know that the old technology cannot be the only solution available forever, for which governments are so accustomed to favor. Innovation and creativity are key factors for engineers and new generations are not able to take us to another level in the application of renewable energies, if no motivation is present. Motivating students for studying new materials, new ways of optimizing devices, new ways of improving monitoring and control of these generations is part of the job of any teacher of the field.

XIII. ETHICAL CONSIDERATIONS IN AI-DRIVEN EDUCATION

Advancements in artificial intelligence (AI) have accelerated the development of intelligent educational technology. Research has recognized that as technology application has not been as popular as expected, there remains an urgent need to further investigate how and why AI should be integrated into education. However, it is important to point out that many of the intelligent technologies used in teaching and learning today have urgent ethical concerns being raised about their use in the field of education. The moral concerns mainly relate to the neo-colonial attitude toward intellective education toward students who are often considered less capable and/or skilled for learning to use AI tools effectively as well as toward faculty who are thought still incapable of doing their workloads without the epistemic support of AI systems. There are also many practical issues surrounding the use of AI in educational practice that relate to the jobs of academic faculty and their responsibilities, as well as how students are being educated.

Additionally, it is acknowledged that, as it is further integrated into our society, AI is expected to challenge how we address the moral and ethical dilemmas of such use, i.e., biases, inconsistencies, fairness, safety, and reliability in the

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fields of education and economy, as well as by compelling the domain of educational research to better inform governmental policies and strategies to regulate the affairs of individuals and institutions in the higher-education ecosystems. Against this backdrop, in this chapter, we will briefly elaborate on, explore, and discuss how privacy and data protection are inverting the field of research and compliance regulations on Artificial Intelligence in education. Furthermore, we delve into the bias and fairness in the higher-education sector, and how they would challenge the design and development of AI systems and reshape the educational scenarios.

13.1. Data Privacy

Cloud technology simplified user access to Generative AI tools. However, these tools require a significant amount of data to run, which raises Data Privacy and Security issues. However, these issues are important in many contexts. In healthcare intent to share data increases after the user recognizes its utility for other users, thus enhancing the importance of Forensic Technologies to ensure the safeguards of sensitive data in this area. In lawyer-client interaction Data Protection must be accounted for. The legal professional has an obligation to protect the confidentiality of the client's information and implement appropriate regulations in this regard. Both parties are obliged to comply with the no-sharing regulation reducing the number of Lawyers allowed to use AI tools in specific circumstances. Partnerships between a bank and a fintech company require also the enforcement of Banking secrecy obligations, including Data Privacy rules. In this context Data Protection must always be taken into account regardless of the nature of the collaboration. Corporate Relationship on the other side are enforced with a Non-disclosure agreement whose breach can have serious consequences.

Some social movements launched Campaigns for Accountable Technology asking the government to restrict the excessive data collection that allows Big Tech to create AI tools. Meanwhile Politicians are thinking about imposing limitations on the maximum period of time for which a company can keep a user's data. For Generative AI tools, this could be a step towards furthering data privacy. Companies must inform users about whether their data are going to be shared, how long they will be stored on the servers, and in which ways they will be used. More generally, developers of Generative AI tools should have Clear and transparent Privacy Policies and clearly communicate to the users the applicable conditions for using the tool, thus reducing the possibility that personal information will not only be stored but misused.

13.2. Bias and Fairness

Bias and fairness are two notable ethical issues that affect AI-assisted education. Many of the widely used AI technology models are trained using online data indiscriminately scraped from the internet. The algorithms rely heavily on the training data, and while some algorithms show impressive capabilities, others produce erroneous algorithms or predictions. The consequences of using AI processes are often unclear, and the bias present in the underlying data can be amplified by the algorithms. AI models essentially internalize the prejudices and preferences of the authors present in such training data, which leads to biased recommendations and unfair treatment of certain groups, cultures, or educations. Bias and fairness are inherently intertwined.

Due to the nature of education, biases and unfairness in AI-assisted educational tools may also provoke issues of justice, particularly in the fields of renewable energy education and climate justice. Generative AI will have a larger effect on facilitating climate change mitigation through renewable energy education if it is used by a more significant number of people and the use is fair to all groups of people. In general, researchers are concerned that the widespread adoption of LLMs will exacerbate existing inequalities, but this concern is particularly relevant for education as students with limited technology use are disproportionately affected by aspects of education quality which correlate with inequality.

For example, at present, the accuracy of generative AI tools may be uneven for different languages, leading lower proficiency students to receive less effective customization support. Furthermore, the outputs from generative AI tools have a generalized preference for both being verbose and discussing subjects that have a propensity to be snarky.

XIV. CONCLUSION

This chapter explored the use of Generative AI tools and cloud technologies to enhance learning in Renewable Energy Education, particularly for BPEE students. The relatively small student cohort for BPEE on its own can hinder the quality of student learning and learning outcomes. The advent of Generative AI tools provides both an opportunity and challenge for educators. These tools are sophisticated, free to use, and remarkably effective at not only generating text, but problem-solving across a variety of disciplines, including engineering. These tools however come with a multitude of challenges including accuracy and reliability of information provided, hallucinations, generation of biased or toxic content, and reliance on cloud technology to function. Incorporating the use of these tools in combination with hands-on learning

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experiences such as cloud-based renewable energy modelling laboratories, or vice versa contributes to deeper learning as difficult concepts are practiced and reinforced. The tools also support the shifting of inventory of learning, particularly implementation, and supporting assets, particularly supplemental.

These tools are disruptive for general technology use. For technical areas such as engineering including for BPEE, they provide disciplinary depth through scaffolding comprehensions and ideas, not passing grades but rather academic aspirations. As we invest focus in optimizing student learning experiences, we also help students reassess their own personal goals and aspirations. This is discipline-wide, but even more heavily skewed for niche areas such as BPEE. Students will focus on their own academic aspirations and helping them utilize Generative AI tools and cloud technologies in an ethically responsible manner is a crucial outcome of their educational experience.

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