How GenAI Transforms Computer Engineering Education: The Case of the Middle East and North Africa

Mostafa Mohamad[1], Dababrata Chowdhury[2], Christopher Russell [3], Ali Balikel[4], Peter Kawalek[5]
[1]Zayed University, College of Interdisciplinary Studies
[2,3]Canterbury Christ Church University
[4]İstanbul Kent Üniversitesi
[5]Loughborough Business School
[1]mostafa.mohamad@zu.ac.ae, [2]daba.chowdhury1@canterbury.ac.uk,
[3]christopher.russell@canterbury.ac.uk, [4]alieren.balikel@kent.edu.tr, [5]P.Kawalek@lboro.ac.uk,

***Abstract*—This research investigates the factors influencing the adoption of GenAI in computer engineering (CE) education within the Middle East and North Africa (MENA) region. The gap in the adoption of GenAI seems to be less pronounced between northern and southern countries compared to other digital technologies. Nevertheless, the academic community has not fully explored the institutional, cultural, and geopolitical factors affecting GenAI adoption. Utilising Harold Linstone's multiple perspectives theory (1981-2019), this study analyses the technical, organisational, and personal viewpoints of 50 CE educators working in higher education institutions in the MENA area. Through an abductive thematic analysis of the interviews and sentiment analysis, the research provides a comprehensive understanding of the GenAI-powered Educational Ecosystem for CE (AEECE) by detailing the essential processes, applications, outcomes, and interactions among the key stakeholders in this ecosystem, including educators, students, university administration, regulators, industry partners, and employers. From a technical standpoint, our findings indicate that GenAI is transforming CE in the region, particularly concerning coding and programming competencies for project management, content creation, and cybersecurity analytics. Other technical insights included innovative practical applications, comprehension of AI's opaque aspects, and limitations in resources. From an organisational viewpoint, we identified that aligning AI investments with the national vision is crucial, as is the need for curriculum reform and addressing resource disparities among various geopolitical contexts. On a personal level, it was noted that educators stepping back from their role as learning facilitators and an excessive reliance on GenAI can undermine critical thinking skills, highlighting the importance of ethical usage and implementation of GenAI applications.**

***Keywords*—GenAI, Multiple Perspectives Theory, Educational Ecosystem, Computer Engineering, MENA region**

***JEET Category*—Research**

I. INTRODUCTION

This paper addresses how Generative Artificial Intelligence (GenAI) is changing everything right now. It can create digital content (including visuals, text, HTML, and coding programs) on its own, flipping the script in pretty much every field you can think of (Zawacki-Richter et.al, 2019). However, there is limited coverage of how university education, especially for Computer Engineering (CE) educators.

GenAI isn't some far-off sci-fi concept anymore. It's already here, baked into the very tools and methods students use every day. This means we can't just keep teaching the same old way and expect graduates to be ready for what's waiting for them out there. With everything from machine learning to chatbots, computer vision to smart robots evolving at breakneck speed, teachers and schools are scrambling to figure out how to make learning experiences that actually matter in this new reality.

The tricky part isn't just slapping some GenAI courses onto what we're already teaching. We need to completely rethink how computer engineering students understand AI's influence across everything they learn. They need the hands-on skills to build and deploy AI systems, sure, but schools also need new structures to support this kind of learning, and everyone involved needs to wrestle with the ethical questions these powerful technologies raise.

This gets even more complicated when you zoom in on the Middle East and North Africa (MENA). With their unique mix of cultural traditions, different levels of tech adoption, and varied economic landscapes, understanding how GenAI education works here specifically is super important. While there's tons of global chatter about AI in education, there's not much research that digs into the real experiences of teachers in this particular region.

Mostafa Mohamad
Zayed University, College of Interdisciplinary Studies,
mostafa.mohamad@zu.ac.ae

This research is based on 50 semi-structured interviews with CE educators from universities across the region to build a comprehensive framework that shows how GenAI is changing CE education from multiple angles. The Multiple Perspectives Theory (Linstone & Mitroff, 1994) has been adopted to look at the technical aspects (the causality and resource-based view), organisational elements (how institutions adapt and the social construction), and Personal dimensions (the human-centric view).

This paper raises some fundamental questions: What challenges and benefits do CE educators perceive when integrating GenAI into their programs? How do CE educators feel (positively, negatively, or neutral) about the evolving impact of GenAI in their main functions, and on the trio (management-faculty-students) relationship that needs to be transformed? How do CE educators see the context of the AI-Powered education ecosystem from the TOP perspectives?

This study is significant for CE academics, students, university management, industry partners, and employers. For academics, it adds valuable new insights to a theory about AI in education. For teachers and school leaders, it offers practical guidance on what works and what does not. And by focusing specifically on the Middle East region, it provides context-specific understanding that can help both local initiatives and global conversations about preparing the next generation of engineers for an AI-powered world.

The pages that follow present a review of the existing literature (to address the gaps). Then, it proposes a systemic theoretical framework based on the multiple Perspectives theory (Linstone & Mitroff, 1994; Linstone, 2019) to structure the fieldwork and the research findings. The discussion section contrasts the key remarks from fieldwork with the literature findings. Then, it proposes a theoretical framework for the Gen-AI Educational Ecosystem for Computer Engineering (or AI-EECE).

II. Literature Review

The educational landscape is witnessing a fundamental transformation with the emergence of GenAI technologies, particularly within engineering disciplines. This review synthesises current scholarship regarding AI's incorporation into higher education broadly, its specific manifestations and obstacles within engineering and computer engineering curricula, the applicability of Linstone and Mitroff's Multiple Perspectives Theory for examining such multifaceted systems, and the value of sentiment analysis methodologies in educational inquiry.

A. GenAI in Higher Education: Global Perspectives

Throughout educational institutions worldwide, GenAI platforms transform the learning environments by customising educational experiences, streamlining administrative functions, delivering intelligent tutoring assistance, and augmenting research capabilities (Zawacki-Richter et al., 2019; Popenici & Kerr, 2017). Higher Education practitioners increasingly explore technological solutions ranging from GenAI-enhanced learning management platforms to sophisticated analytics systems for monitoring student achievement. Nevertheless, this optimism is counterbalanced by ethical considerations regarding algorithmic prejudice, information privacy protections, potential socioeconomic learning disparities, and implications for students' critical reasoning abilities and interpersonal engagement (Selwyn, 2019; Bozkurt et al., 2021). So, what does the literature report about the Benefits and challenges of adopting GenAI in higher education?

1) GenAI Benefits & Challenges in Higher Education

The discourse surrounding GenAI in higher education is often balanced between its transformative benefits and inherent challenges. Key benefits frequently cited include the potential for personalised learning at scale, improved accessibility for students with diverse needs, automation of routine administrative and instructional tasks, and the ability to provide students with skills relevant to an increasingly GenAI-driven workforce (George, 2023; Somasundaram et.al., 2020). GenAI can also assist research through the quickening process of data analysis, simulation, and discovery processes.

There are many challenges associated with the integration of GenAI in higher education that have been frequently reported in the literature. Ethical implications, including data privacy, algorithmic fairness in decision-making processes (e.g., in admission or assessment), and the risk of perpetuating current biases, are top concerns (Elish, 2019). Academic integrity in the face of powerful GenAI tools also requires new assessment methods and an emphasis on critical thinking skills. Additional challenges are represented by the expense of the infrastructure and the tools of GenAI, forward-looking faculty development and training needs, the digital divide constraining equitable access, and the over-reliance risk and subsequent diminution of core capabilities (Finnie-Ansley et.al., 2022). The fast pace at which GenAI is developing also renders curriculum and institutional policy hard to keep up with, especially in CE education.

2) GenAI's Role in Computer Engineering Education

CE's educators adopt GenAI to perform diverse and dynamic roles (See Figure 1). It is no longer a study subject, but an applied tool that can enhance teaching methods (including course design, delivery, and assessment). GenAI techniques are being diffused into various engineering disciplines to address wicked problems and solve complex challenges, refine designs, and streamline processes (Graham, 2018). When it comes to computer engineering, the curriculum is rapidly adapting to include essential GenAI concepts, machine learning, data science, robotics, and specialised applications of agentic AI (Acharya et.al., 2025). The real challenge is keeping up with the fast-paced technological changes and ensuring that graduates not only have the technical skills but also a solid grasp of the societal and ethical implications tied to GenAI (Boddington, 2017). Teaching models are shifting towards more hands-on, project-based learning, giving students practical experience with AI tools and platforms (Mills & Treagust, 2003).

The last three years witnessed a surge in the scholarly work that addresses the adoption of GenAI technologies within various facets of CE education. GenAI applications range from intelligent tutoring systems (ITS) designed to provide personalised learning support and feedback (Sottilare & VanLehn, 2020), to AI-driven platforms for automated grading and assessment, which aim to reduce faculty workload and offer timely evaluations to students (Gnanaprakasam & Lourdusamy, 2024). The pedagogical utility of GenAI-based code generation utilities, exemplified by platforms like GitHub Copilot, is a subject of ongoing inquiry within programming education, yet this investigation concurrently sparks critical discourse concerning their influence on the cultivation of essential, rudimentary programming competencies (Finnie-Ansley et.al., 2022).

GenAI is being utilised for learning analytics, enabling educators to track student progress, identify at-risk students, and tailor pedagogical strategies accordingly (Siemens & Baker, 2012). The use of GenAI in simulating real-world engineering problems and facilitating project-based learning is also gaining traction, preparing students for the complexities of professional practice (Lythreatis et.al., 2022).

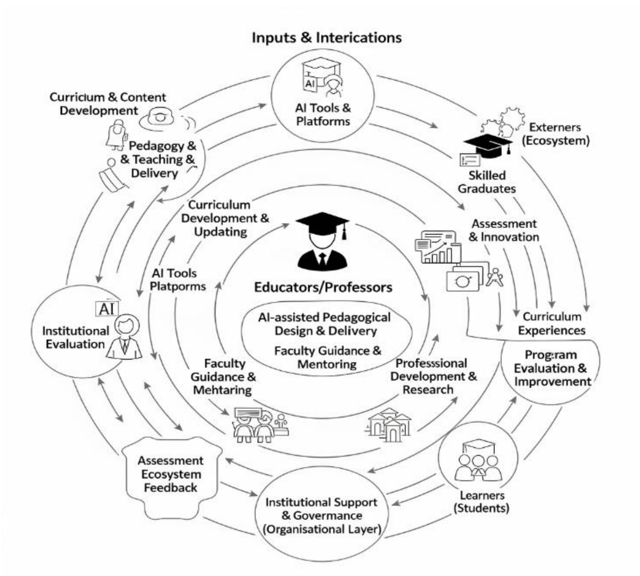

Fig. 1. The educational functions and processes in CE

A prevailing sense of positive anticipation permeates scholarly discussions regarding the capacity of GenAI to render engineering pedagogy more responsive to individual learner needs, captivating in its delivery, and streamlined in its execution. Nevertheless, this body of work also underscores the embryonic nature of numerous AI-driven educational tools and emphasises the imperative for robust, evidence-based research to substantiate their instructional value and ascertain their wider consequences (Vassilakopoulou & Hustad, 2023).

B. Multiple Perspectives Theory: A Framework for Analysis

The abovementioned phenomenon requires a systemic understanding of the challenges, benefits, stakeholders, and the adoption mechanisms of GenAI into engineering education. Linstone and Mitroff's Multiple Perspectives Theory (MPT) is a systems thinking theory that helps develop a framework for tackling complex, poorly defined issues, like how to integrate AI into educational systems (Linstone, 2019; Phillips & Linstone, 2016). As Table I, suggests MPT works as a system that helps look at complex systems from at least three different angles: the Technical (T) perspective, which focuses on problem-solving, models, data, and efficiency; the Organisational (O) perspective, which deals with policies, structures, processes, and the interests of stakeholders; and the Personal (P) perspective, which emphasizes individual intuition, creativity, values, and motivations. This approach has been applied to various complex systems, and its value in analysing educational changes, which are inherently socio-technical, is becoming more widely acknowledged (Linstone & Mitroff, 1994). However, using it specifically to address the challenges and advantages of AI in computer engineering education, especially through extensive empirical research, is still a promising area for further investigation.

TABLE I
DESCRIPTION OF THE MULTIPLE PERSPECTIVES THEORY (LINSTONE & MITROFF, 1994:15)

	T	O	P
World view	Science/technology problem solving	Group/institution process, action	Individual, self power, prestige
Ethical basis	Objectivity	Fairness, justice	Morality
Mode of inquiry	Analysis, observation, cause–effect	Satisficing, bargaining, agenda	Intuition, Learning, challenge – response
Planning horizon	Far	Moderate discounting	High discounting for most
Uncertainty view	Uncertainties noted	Uncertainties used	Uncertainties disliked
Risk criteria	Logical soundness	Political acceptability	Loss-gain imbalance
Scenarios	Exploratory	Preferable	Visionary

While existing scholarship addresses various aspects of GenAI in education, a significant gap persists regarding holistic, multi-perspective frameworks grounded in diverse, in-depth qualitative data from specific regional contexts such as the MENA region. Much current research focuses narrowly on specific GenAI tools, pedagogical interventions, or general ethical concerns, often without providing a systematic view integrating technical, organisational, and personal dimensions cohesively.

III. RESEARCH METHODOLOGY

This paper aims to answer the question of "*How does GenAI revolutionise the Computer Engineering Education?*" In doing so, it attempts to explore the key functions in CE education, the benefits and challenges of adopting GenAI (See Figure 1). The study also reflects a contextual understanding of how computer engineering education perceives the overall GenAI-powered educational ecosystem in their countries and in their higher education programmes. The digital divide is a well-known phenomenon that arises with every technological wave and reshapes the innovative practices in every domain (Carter & Cantrell, 2020). The digital divide in GenAI does not follow the same patterns that took place on the Internet of Things, Cloud Computing, and Augmented Reality. The MENA region offers a special context, where countries such as the UAE and KSA lead the GenAI development and revolutionise their education. Accordingly, this research selected the MENA context to uncover this untapped context.

GenAI is shaking things up in computer engineering education across the Middle East and nearby regions. So, we decided to talk to educators directly, using an interpretative philosophy and qualitative approach to build a context-related understanding of the phenomenon. Our big aim was to build a strong, practical understanding from the ground up, using Linstone and Mitroff's Multiple Perspectives Theory as our guide. We picked this theory because it's great for understanding the messy, real-life experiences and different viewpoints of professors who are trying to weave AI into their classrooms and universities.

The multiple perspectives theory is good at capturing all the complex, sometimes tangled, and very human experiences of educators who are in the thick of bringing GenAI into their teaching and their universities (Mohamad, 2015; Mohamad & Eldarmi, 2020). To explore this, the authors of this paper decided to approach a purposive sample of 50 participants (See Table II) who serve as professors, senior lecturers, and lecturers in the top 50 MENA institutions that heavily adopt GenAI in their computer engineering programmes (MITSloan-Middle East, 2023). We used semi-structured interviews because this was new ground for us, and we wanted to have genuine conversations. This approach lets you hear the detailed stories, the personal 'aha!' moments, and get a real feel for the context in a way that just crunching numbers cannot (Creswell & Poth, 2018). We had a guide for our chats, but we also made sure there was plenty of room to follow interesting threads that came up naturally. The interview participants work in computer engineering at the Undergraduate and Postgraduate levels. 34% of the selected universities offer applied education, while 66% offer standardised BSc and MSc in computer engineering.

The data analysis methods included abductive thematic analysis and sentiment analysis (Braun & Clarke, 2006). The initial themes were Linstone and Mitroff's Technical, Organisational, or Personal perspectives. Then, sentiment analysis of the interview transcripts was conducted to capture the contextual experience and feelings behind the words (Han & Moghaddam, 2021). Such analysis helped capture positive, negative, and neutral feelings to add that emotional flavour to what we found in the interviews. Sentiment analysis is a statistical technique to tap into the opinions hidden within text. It helps the researchers to sort out whether participants are expressing positive, negative, or neutral views, and it's shown its worth time and again in educational studies. This technique has been adopted to ensure a balanced approach for building a systemic framework of Educational Ecosystem for Computer Engineering (See Mohamad, 2025). To run Sentiment analysis, this paper employed Python programming for Data analytics and the procedures suggested in Sahoo et.al (2019).

The researchers of this paper have used it to effectively gather educators' feedback, understand gut reactions to new technologies, and even assess how well learning experiences are landing (Sailun & Alhajj, 2019; Pardos & Dadu, 2020). In this study, it has been used to understand the feelings and attitudes of the educators themselves. This is not just about facts and figures; we want to capture the emotional side of things to give us a richer picture of the Technical, Organisational, and Personal dimensions as they bring GenAI into their world.

TABLE II
LIST OF INTERVIEWEES

Professor ID	Country	Specialty	Educational Function	GenAI Used in Education
P01	Saudi Arabia	AI & Robotics	Teaching, Research	GitHub Copilot
P02	UAE	IoT Security	Teaching, Industry Collaboration	IBM QRadar Advisor with Watson
P03	Egypt	Digital Signal Processing	Teaching, Project-Based Learning	MATLAB (Deep Learning Toolbox), Python (TF/Keras)
P04	Turkey	Software Engineering	Teaching AI Ethics	ChatGPT (GPT-4)
P05	Iran	Computer Architecture	Teaching, Research	TensorFlow, PyTorch, Google Colab
P06	Qatar	Human-Computer Interaction	Teaching	Figma (AI plugins), Google Teachable Machine
P07	Kuwait	Data Science	Teaching, Curriculum Alignment	Azure Machine Learning Studio
P08	Oman	Computer Networks	Teaching	Scikit-learn, SolarWinds NTA
P09	Bahrain	Embedded Systems	Teaching	Edge Impulse
P10	Jordan	Natural Language Processing	Teaching, Research	Hugging Face Transformers, Google Colab Pro
P11	Lebanon	Robotics & Autonomous Systems	Teaching, Research	ROS, OpenCV, TensorFlow Lite
P12	Iraq	Computer Vision	Teaching	OpenCV, Scikit-learn
P13	Palestine	Software Engineering	Teaching, Grading	Tabnine, Gradescope
P14	Saudi Arabia	AI and Ethics	Teaching	Google AI Platform, TensorFlow, AI Fairness 360
P15	UAE	Cybersecurity & Network Engineering	Teaching	Splunk (MLTK)
P16	Egypt	Machine Learning	Teaching	Python, TensorFlow, Keras, Scikit-learn
P17	Turkey	Natural Language Processing	Teaching, Research	Hugging Face, Prodigy
P18	Qatar	AI in Healthcare	Teaching, Research	NVIDIA Clara, TensorFlow, PyTorch
P19	Jordan	Cybersecurity	Teaching	Palo Alto Cortex XSOAR
P20	Saudi Arabia	Computer Vision	Teaching	MATLAB, OpenCV, TensorFlow/Keras
P21	UAE	Educational Technology	Teaching, Tool Development	Carnegie Learning MATHia, Python (NLTK)
P22	Egypt	Control Systems & Robotics	Teaching	Simulink, ROS, Python AI libs
P23	Turkey	High-Performance Computing	Teaching	NVIDIA CUDA, OpenCL, Nsight
P24	Qatar	Machine Learning	Teaching, Experiment Tracking	Google Colab Pro, Weights & Biases

P25	Oman	Data Analytics	Teaching	KNIME
P26	Kuwait	Software Systems	Teaching	Amazon CodeWhisperer
P27	Bahrain	AI Applications	Teaching	Google Dialogflow
P28	UAE	Cloud Computing & Big Data	Teaching	Databricks (Apache Spark)
P29	Lebanon	Bioinformatics	Teaching, Research	Biopython, Scikit-learn, DeepVariant
P30	Syria	Database Systems & AI	Teaching	Python (basic), Offline Docs
P31	Saudi Arabia	Cybersecurity	Teaching	Cyberbit, Metasploit
P32	UAE	Smart Cities & IoT	Teaching	AnyLogic, TensorFlow
P33	Egypt	Robotics and AI	Teaching	NVIDIA Isaac SDK, OpenAI Gym
P34	Turkey	Data Mining & ML	Teaching	RapidMiner, Python (SHAP, LIME)
P35	Qatar	IT & Basic Programming	Teaching	Replit (Ghostwriter AI)
P36	Jordan	Networks & Security	Teaching	Wireshark, Python (Scapy), Scikit-learn
P37	Saudi Arabia	AI & Smart Systems	Teaching, Research	AutoKeras, H2O.ai AutoML
P38	Oman	Programming & Web Dev.	Teaching	Coursera/EdX (AI grading), GitHub Copilot
P39	Lebanon	Signal & Image Processing	Teaching	MATLAB, OpenCV, TensorFlow/Keras
P40	UAE	Computer Information Science	Teaching	Microsoft Power Platform (AI Builder)
P41	Egypt	Embedded Systems & IoT	Teaching	Arduino/Raspberry Pi, TensorFlow Lite
P42	Turkey	Computational Linguistics	Teaching	Python (NLTK, SpaCy), Hugging Face
P43	Oman	Software Engineering	Teaching	Turnitin (AI), AI test generators
P44	Kuwait	Data Management	Teaching	Oracle Autonomous Database
P45	Saudi Arabia	Information Security	Teaching	Snort (ML), Python, Zeek logs
P46	Palestine	Computer Systems Engineering	Teaching	Gazebo, ROS, OpenCV
P47	Jordan	Industrial Automation & AI	Teaching	Siemens MindSphere
P48	Qatar	Avionics/Critical Systems	Teaching	Cameo Systems Modeler (AI plugins)
P49	Turkey	Game Development	Teaching	Unity/Unreal AI plugins
P50	Yemen	Software Engineering	Teaching (Basic)	Python (local use), Textbooks

IV. RESEARCH ANALYSIS & FINDINGS

This section presents the data collected from primary sources, including Semi-structured qualitative interviews and sentiment analysis. The interview data is analysed using abductive thematic analysis. Initial themes are present in the trio perspectives: Technical (T), Organisational (O), and Personal (P). Then, inductive tree coding was used to develop sub-themes. The codes and analysis for both the interview transcripts and the sentiment analysis were conducted using Python analytics (See appendix 1) (Sahoo et.al, 2019).

A. Analysis of Qualitative Interviews

This section presents the researcher's interpretations of the computer engineering educators on how GenAI revolutionise computer engineering schools across the Middle East and nearby countries. Initial themes were Technical, Organisational, and Personal perspectives, while subthemes were developed based on an inductive analysis of the interview transcripts. Then, a thorough explanation of the sentiment analysis is presented to clarify the interplay between the technical, organisational, and personal views adopted by the educators to develop a systemic framework for a GenAI-powered education ecosystem.

1) Technical Perspective (T)

This perspective focuses on the causality and resources-based view of the computer engineering educators, including the GenAI tools, platforms, pedagogical applications, and the inherent technical challenges and benefits.

Theme T1: Proliferation and Diversification of AI Tools in Pedagogy

CE educators adopted a wide range of AI tools for general-purpose coding assistants to specialised CE platforms. P1, for example, said, *"We use GitHub Copilot extensively in our advanced programming... It accelerates coding, shows students different ways to solve problems."* This was echoed by P13, who mentioned, "*We are cautiously introducing AI-powered coding assistants like Tabnine*." While the former participant reflects the open appetite for adopting GenAI in KSA, the latter participant reflects the sceptical view of adopting it in the Palestinian education system.

Security analytics is a domain-specific application that is highly demanded in the UAE. P2 highlighted *"we use IBM QRadar Advisor with Watson for teaching security analytics*" in the undergraduate programme for cybersecurity. In another specialised programme for embedded systems in Bahrain, P9 said, "*We rely on Edge Impulse for teaching TinyML*".

The adoption of GenAI ranges from foundational tools to develop basic skills for mainstream CE to advanced platforms tackling complex engineering problems, indicating a broad technical integration in specialised programmes such as cybersecurity, embedded systems, and security analytics. The adoption ranges from applied active learning pedagogy for CE in the UAE and Bahrain to inclusive education in KSA. It seems that different levels of diversity of educators in different Gulf countries lead to different levels of GenAI adoption and different pedagogies adopted by the educators who come from different cultural backgrounds and different technical experiences.

Theme T2: Enhancing Learning Through Practical Application and Simulation

GenAI tools were widely used to support students in developing problem-solving skills and to simulate real-life situations. Simulation development and gamification offer zero-risk experiential and now, "we use ROS to develop games for lean manufacturing, interior design, and business trading", said P11 from Lebanon. "*With AI perception packages... on platforms like NVIDIA Jetson Nano, our students integrate AI for tasks like object recognition, navigation, and SLAM*, "he emphasised.

A UAE-based faculty, P32, discussed the adoption of GenAI in smart city programmes. For our students*, "using simulation platforms like AnyLogic (with its AI capabilities) and real IoT sensor data with Python/TensorFlow are daily routines for developing AI-powered smart city applications."* Such a way of bridging theory and practice by launching the technical capability of AI to model simulation is making learning more tangible and relevant.

Theme T3: The "Black Box" Dilemma and the Imperative of Foundational Understanding

CE educators struggle to maintain a careful pedagogical balance by ensuring students understand the underlying principles of GenAI rather than just using tools as "black boxes." From a technical perspective, "*Appreciating MATLAB's Deep Learning Toolbox does not mean ignoring the underlying mathematics of such technology and treating it as a black box*", noted P3.

Emphasising the same issue, P4 "*believes that ChatGPT (GPT-4) generates plausible but incorrect information. Unless we critically evaluate its output, we will fall into a black box*". While P3 reflects his experience in teaching BSc Communications and Computer Engineering in Egypt from an applied pedagogy, P4 reflects the Turkish experience of teaching software engineering from a theoretical pedagogy. CE educators are technically aware that the power of AI tools must be coupled with robust pedagogical strategies that reinforce fundamental concepts to avoid superficial learning.

Theme T4: Resource Constraints and Access Disparities

Access to cutting-edge GenAI platforms, computational resources (especially GPUs), and large, high-quality datasets remains a significant technical hurdle, particularly in less affluent or sanctioned countries. P5, from Iran, stated that

> "*Access to some commercial GenAI platforms can be challenging due to sanctions, so we heavily rely on open-source tools like TensorFlow and PyTorch... The main technical hurdle is often computational resources*."

Adding to this challenge, P12 from Iraq, lamented that "*Access to cloud platforms or expensive GPUs is limited... The main technical challenge is the lack of computational power for more advanced deep learning models for vision*." This was starkly put by P50 from Yemen, "*The sheer lack of electricity, internet, and modern hardware is the primary technical barrier.*"

Overall, the technical adoption is heavily influenced by resource availability, creating a digital divide in AI education capabilities within the region. Open-source tools are crucial in mitigating some of these disparities.

2) Organisational Perspective (O)

This perspective examines institutional strategies, policies, resource allocation, curriculum development, faculty support, and external collaborations related to GenAI integration. In this section, we present the findings that support four themes as follows.

Theme O1: Strategic Alignment with National Visions and Institutional Investment

Universities in the MENA region, and those that operate in Gulf countries, align their GenAI strategies with national goals and the UN sustainable development goals. In consequence, there is accelerated institutional support and investment. For example, P1 from KSA stated that *"Our national Vision 2030 pushes for tech self-sufficiency, so these skills are paramount."*. P14 similarly noted that "*Saudi universities get limitless government support to empower women in tech and establish facilities and cloud resources to improve their GenAI literacy*."

P6 from Qatar reaffirms this alignment by saying that "*Qatar National Vision 2030 emphasises a knowledge-based economy. Our university is investing..."*. So, it seems that top-down governmental policies are the key drivers for the successful adoption of GenAI in education in general and computer engineering more specifically. This organisational change, led by the government, reshaped how universities in the region facilitate resource allocation and strategic prioritisation of GenAI in education.

Theme O2: Curriculum Reform and Integration Across Disciplines

Designing a GenAI-powered educational ecosystem requires active reform of curricula to include dedicated GenAI courses, specialisations, and integrating AI concepts across various CE subjects, moving beyond AI as a siloed topic. P2 from UAE said that "*Curriculum-wise, we've introduced dedicated modules on AI in Cybersecurity*". Confirming the same procedures, P10 from Jordan, mentioned their "*M.Sc. Computer Engineering (AI specialisation) requires cross learning objectives and outcomes to be redesigned across their other UG and PG programmes to ensure consistency in delivery and evaluation techniques*."

This would also affect the accreditation process and how accreditation bodies for engineering education would evaluate programmes in the MENA region. Based on the approved narratives, we can see that organisational efforts are focused on embedding GenAI comprehensively within CE education, reflecting its pervasive impact on the field of engineering education in general.

Theme O3: Faculty Development and the Challenge of Expertise

Effective adoption of GenAI in CE requires new routes for professional development that raise organisational challenges, including the costs of recruiting professionals and AI developers to train faculty. There is a continuous demand for up-to-date knowledge and skills to effectively teach GenAI and utilize AI-powered pedagogical tools.

P7, from Kuwait, "*developing an advanced faculty development programme to help them master GenAI applications for CE is a hurdle. We had to develop our own cloud platforms for a list of training courses, including third parties*".

In addition, "*Continuous upskilling is a must. Our faculty should be entrepreneurs in GenAI…, Natives of this technology, not immigrants who follow the fashion*", said P36 from Jordan.

It seems that CE educators and their institutions recognise the need for ongoing professional development, but providing adequate and timely training remains a significant operational challenge.

Theme O4: Addressing Academic Integrity and Ethical AI Use

The rise of powerful GenAI tools necessitates organisational responses in terms of policies on academic integrity and the integration of AI ethics into the curriculum.

P4, from Turkey, reported that "There's a university-wide debate about academic integrity. We're developing guidelines for ethical AI use. We've integrated AI ethics modules into our curriculum". In Oman, P43 confirmed the proactive procedures by saying that "*piloting the use of AI-powered plagiarism detection tools... like Turnitin with its AI writing detection features is a challenge for CE. How can we detect codes developed by GenAI platforms for software development projects?*"

So, there are higher education institutions in the region that replicate policies developed by Western institutions in the US and European countries, while others are ahead in their innovative policies that allow agile adoption of GenAI in software development and other areas of CE education. In the MENA region, organisations seem to be grappling with the disruptive potential of GenAI on academic norms and are trying to proactively instil ethical awareness.

Theme O5: Resource Disparities and Geopolitical Impacts on Organisational Capacity

The economic conditions and geopolitical factors create a wide variation in the level of GenAI adoption and organisational capacity for CE.

P11, from Lebanon, observed that, "*Despite economic challenges in the country, our institution strives to maintain high standards. We rely on industry collaborations and grants*". In contrast, P30, from Syria, explained, "The primary goal is to keep education going... International collaborations or access to online platforms are scarce and difficult". It seems that the organisational capacity for GenAI integration is not uniform; external socio-economic and political factors play a crucial role in shaping institutional capabilities and responses.

P32, from UAE, confirmed that; "*Our country is a world leader in GenAI in terms of investments and collaboration with Silicon Valley giants. Though relying on open-source GenAI platforms raises cybersecurity concerns and control over our creative projects when we upload every piece into the open source"*.

So, even though operating in strong economic conditions and advantageous geopolitical situations, organisational capacity for GenAI adoption could be challenged by cybersecurity and privacy regulations. Accordingly, the technical perspective might reshape the organisational capacity and limit the wide adoption of GenAI in CE.

3) Personal Perspective (P)

This perspective captures the individual attitudes, beliefs, motivations, concerns, and experiences of the CE educators (Linstone, 2019).

Theme P1: Enthusiasm and Excitement for GenAI's Pedagogical Potential

Many educators expressed genuine excitement about GenAI's ability to enhance student engagement, facilitate deeper understanding, and make learning more dynamic and relevant. P3, from Egypt, shared his view: "*My students feel amazed by the A-Powered image classifier that seems to work effectively! It is rewarding for media and communication projects. Our clients from the community perceive these images as satisfactory too!*" So, it seems that GenAI can boost educators' passion toward active learning and teaching innovation. P9, from Bahrain, affirms this passion by saying, "*It is fantastic to see students build... a voice-controlled device or a simple gesture recognition system on a tiny chip*." His experience teaching on-device inference has been transformed by the adoption of GenAI. Students in his courses moved from technical struggles towards innovative solutions for people with special needs.

Educators' personal motivation and vested interests are fueled by the positive impact that GenAI has on their students' learning and creativity. GenAI seems to create a roller-coaster impact on student-teacher relationships and the quality of the CE education overall. This enhances the self-image of educators and encourages them to create new pedagogies.

Theme P2: Concerns about Over-Reliance and Erosion of Fundamental Skills

CE educators expressed their concerns about overdependency on GenAI for fundamental tasks such as coding and problem-solving activities.

A significant personal concern among educators is that students might become overly reliant on AI tools, potentially leading to a decline in their fundamental problem-solving and coding abilities. P1, from KSA, was worried that "*skill fade' in fundamental coding would occur if students became too reliant on GenAI. It's a constant balancing act. We cannot build a penthouse with no basement!"*.

P35, from Qatar, voiced his caution that "*the heavy use of Replit (Ghostwriter AI) degrades students' ability to develop fundamental problem-solving skills and makes it difficult for us to teach them new advancements. The shift from GenAI to agentic AI needs strong problem-solving and analytical skills"*.

CE educators perceive high dependency as a personal responsibility, and it is their duty to ensure that GenAI tools are used as aids to learn, not as crutches that undermine core competencies.

Theme P3: The Evolving Role of the Educator – From Lecturer to Facilitator

The expansion of GenAI applications in different tasks of CE led to a shift in the educators' roles from being instructors to learning facilitators who guide the student through AI-assisted work. Educators' role is to offer resources and critically evaluate how students use GenAI to develop creative solutions to empirical problems.

P4, from Turkey, confirmed that she is no longer a traditional teacher who delivers coding scripts for UG students; rather, she facilitates coding games and design experiments, where students engineer a diverse set of prompts to get outputs. She said, "*I use Socrates.AI as a mentor for my software development classes. I simply develop a scenario and sit in the background to see how students interact with the experiment*".

P40, from UAE, confirms that his role is to ensure students understand the capabilities and limitations of GenAI models and use them responsibly. He said, "*I facilitate how my students use low-code GenAI application building for process automation, but I don't show them how! I let them try and try again…I simply facilitate and create a peer-learning mechanism and space for work*".

So, it seems that GenAI is prompting a personal re-evaluation of teaching identity and pedagogical approaches among CE educators. It also puts educators at risk of being replaced by agentic AI that are robotised.

Theme P4: Ethical Considerations and the Drive for Responsible Innovation

CE educators have taken a personal stake in enhancing the GenAI ethics as well as its applications. The interview data showed strong evidence of how CE educators' sense of personal responsibility regarding these principles. For example, P2, from UAE, emphasised, "*It's not just about the tech; it's about responsible innovation.*" She also referred to the UAE ethics legislation that is widely adopted by all educators in the country (See MoSAI, 2022). Such legislation demonstrates that the personal orientation turned out to be a national quest to assure ethical use of GenAI for innovative life solutions rather than to replicate artefacts with no originality.

P10, from Jordon, shared her "*concern is the ethical use of powerful language models*". She has taken the initiative of developing professional development for faculty on the ethical use of GenAI and founded a community of practice to ensure all modern and up-to-date strategies are followed while the adoption of GenAI is spreading among educators and students. In the same direction, P14, from KSA, stated, "*My personal mission is to ensure students are not just skilled technicians but also ethical leaders in GenAI*".

It seems that educators in affluent countries with rich resources have taken the lead in developing a personal code of practice towards the weight of preparing students to be not just technically proficient but also ethically responsible GenAI developers and users.

Theme P5: Resilience and Dedication in Resource-Constrained Environments

CE in the MENA region presented a high level of resilience towards the resource-constrained environment. The Forbes newspaper published the early foundation of OpenAI as a non-profit organisation that was expected to stay open for all users regardless of their geographical location or their income (Forbes, 13th of Oct 2023). However, the company shifted their ownership structure into a profitable business model that offers premium versions to specific countries and to users who can afford it.

P12, from Iraq, stated, "*OpenAI was restricted to the US and Western countries at the beginning and then moved toward a subscription model. Securing a budget and getting appropriate training for premium versions was not accessible to all educators.*" Despite these challenging contexts, they displayed remarkable personal resilience, dedication, and a deep commitment to their students despite severe limitations. "*It's challenging but also rewarding. The students are very eager to learn, and we had to develop a best-of-breed portfolio of GenAI applications to develop a complete learning experience*", confirmed P12.

P50, from Yemen, "*It is heartbreaking to see the potential of bright students hampered by the situation. We try to keep their spirits up. They need to keep up with the AI literacy*". P 46, from Palestine, confirms the same dedication and resilience, saying, *"I am constantly amazed by the students' ingenuity and their ability to achieve so much with so little."*

The above findings confirm that the personal orientation and commitment of CE educators are powerful forces sustaining education under duress, highlighting the profound human element in the educational ecosystem.

A. B. Sentiment analysis

Following a thematic transcription, sentiments were pointed out in each theme. The illustrative quotes were qualitatively assessed. Sentiments were screened based on frequency of keywords, phrases, and the overall tone to determine whether the expressed view was positive (enthusiastic, optimistic, highlighting benefits), negative (critical, concerned, highlighting challenges or drawbacks), neutral (factual, descriptive without strong emotional leaning), or mixed (containing both positive and negative elements, or expressing ambivalence). The positive sentiments were used to point out the benefits of GenAI in CE education, while the negative ones were used to summarise the challenges faced by the educators.

1) Sentiment polarity by perspective

The first step in analysing sentiment polarity by perspective (See Figure 2). The technical sentiments show the lowest average polarity, reflecting a more critical or neutral stance. CE educators often highlight practical limitations, such as tool accuracy, computational constraints, or student over-reliance on GenAI. For instance, a sentiment by P40 states that, *"GenAI is a tool, not a replacement for understanding algorithms."*

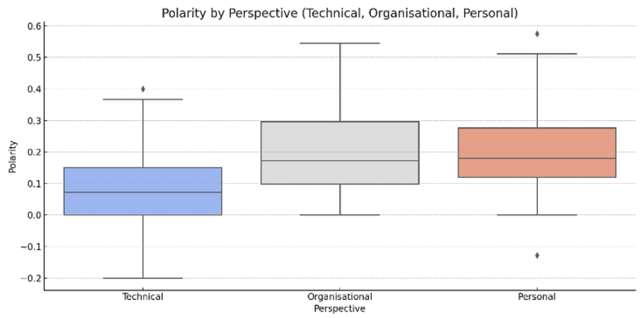

Fig. 2. Sentiment Polarity by perspective

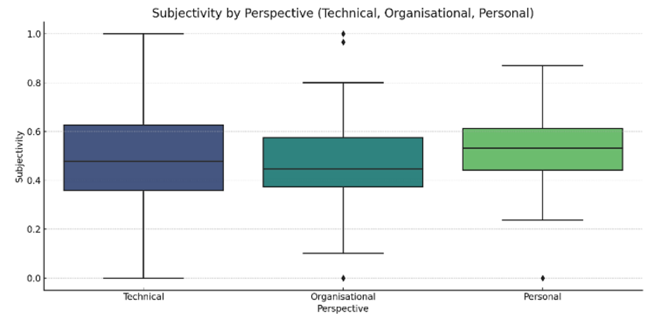

Fig. 3. Sentiment Subjectivity by Perspectives

The organisational sentiments hold the highest positivity, due to institutional support, national visions (e.g., Vision 2030 in KSA and Vision 2050 in UAE), and curriculum innovation. For example, P43 said that *“We secured licenses and integrated Copilot into our LMS.”*

The personal sentiments are relatively positive but tempered with ethical or pedagogical concerns. An example is presented in a statement by P35, *“GenAI frees up my time, but I worry about skill fade.”* CE educators express personal satisfaction, pride, but also anxiety about GenAI’s impact on human-centred learning and problem-solving skills.

Appendix 3A presents the scales of sentiments from different perspectives and adds further details to the figure above. The scales of technical and organisational sentiments are more balanced, often grounded in objective evaluations of performance, infrastructure, and policy changes.

2) Sentiment Subjectivity by Perspective

The second step is analysing sentiment subjectivity by perspective as shown in Figure 3.

Technical sentiments presented mid-level of subjectivity (See Appendix 3B). Despite the causal and factual nature of technical views, the sentiments are not devoid of subjectivity. For example, P4 expressed a technical perspective using statements such as *“The pedagogical effectiveness of GenAI tools”, “Concerns over students using GenAI as a crutch”, and “The tension between automation and comprehension”.*

As shown in Figure 3, the subjectivity of technical sentiments is still notable, which reflects how tool evaluations were rarely neutral. Even technical analysis was coloured by experience-based insights (e.g., how GenAI changed classroom dynamics or grading). This reflects the sociotechnical nature of the GenAI-powered education ecosystem. It blends pedagogy with technology, where technical choices have emotional and ethical consequences.

Organisational sentiments reflected the Lowest Subjectivity, despite being the most neutral. The CE educators reflected their organisational perspective using personal and political overtones. For example, P45 used expressions such as: “*Institutional readiness and government vision (e.g., Vision 2030 in Saudi Arabia)*”, “Challenges *like faculty training gaps or access inequalities”, and “National pride in tech innovation”.*

As demonstrated in Figure 3, the lower variance and narrow range in the boxplot support the assumption that organisational insights were often policy-driven, structural, and pragmatic. However, they still carry emotions such as pride, frustration, or optimism, which often colour institutional commentary. These results clarify how national agendas and funding shape the GenAI conversation, especially in tech-forward countries like the UAE and KSA, versus more resource-constrained ones like Yemen and Palestine.

Personal sentiments are the most subjective that encompassing the emotions, fears, and hopes of CE educators. Such views validate the human-centred insights gathered in the qualitative interviews. Examples of pure subjectivity are mentioned by P49, while reflecting his personal view in the Turkish context as follows:

> *“I worry about the skill fade”* – to reflect his emotional labor.
>
> “*Are we encouraging dependency?*” – to reflect his Ethical dilemmas.
>
> “*My mission is to prepare ethical GenAI leaders*” – to reflect Cultural alignment.
>
> “*Seeing my students build things on limited hardware is incredibly rewarding*” – to reflect fulfilment and passion.

As shown in Figure 3, the wider spread in the boxplot for personal subjectivity reflects diverse emotional and reflective feelings. The sentiments express excitement, concern, and sometimes frustration due to resource limitations, especially in Palestine, Yemen, Syria, and Iraq. Accordingly, the GenAI-powered education ecosystem is a complex system where human experience and technological co-evolve to deliver a transformative learning context.

3) Multiple Perspectives Sentiment Analysis

This section addresses the balance/imbalance between the Technical, Organisational, and personal views and how each perspective carries positive, negative, or neutral meanings. The positive sentiments have been grouped to point out the benefits, while the negatives have been classified as challenges (See Figure 4).

The *technical sentiments* were 35% based on phrases such as: P33 mentioned “*My students were excited about the capabilities of new GenAI tools and platforms (e.g., cloud ML platforms, specialised AI software for robotics, etc.) and their potential to enhance learning and enable complex projects”.*

30% were negative to address challenges such as "rapid obsolescence of specific GenAI tools and the difficulty of keeping curricula current", said P10. Another negative sentiment by P30, "*Frustration with the high cost and accessibility issues of advanced GenAI software, hardware (especially GPUs), and reliable internet, particularly in resource-constrained institutions or regions*".

35% of the technical sentiments convey mixed feelings, such as "*Balanced discussions on the pros and cons of using AI coding assistants (e.g., GitHub Copilot) – recognising their utility for productivity but also the risk to foundational learning*", said P38.

Organisational sentiments included 25% positive expressions such as: "*Optimism when strong institutional strategy, leadership, and vision drive GenAI integration efforts"*, said P5 from Iran. Another positive statement mentioned by P20 from KSA, "*Appreciation for government initiatives and national AI strategies that support AI in education through funding and policy"*.

45% were negative sentiment expressing issues of limited resources, like what P30 from Syria mentioned, "*Concerns about the digital divide between institutions and the inequitable distribution of resources.*" National-level challenges were expressed by P50, "*Challenges highlighted by institutions in conflict zones or facing severe economic hardship, making AI adoption extremely difficult for us*".

30% of the organisational sentiments were Mixed/Neutral, describing the status quo. For example, P46 from Palestine, "we need sustainable models for accessing commercial AI tools, often presenting it as a challenge requiring a solution". Another neutral expression is "*accreditation requirements and their influence on GenAI integration*", said P8 from Oman. Overall, most of the organisational sentiments are either neutral or negative, carrying signs of frustrations regarding funding, institutional agility, and resource disparities. Positive sentiments cover only strong leadership and strategic initiatives in the long run.

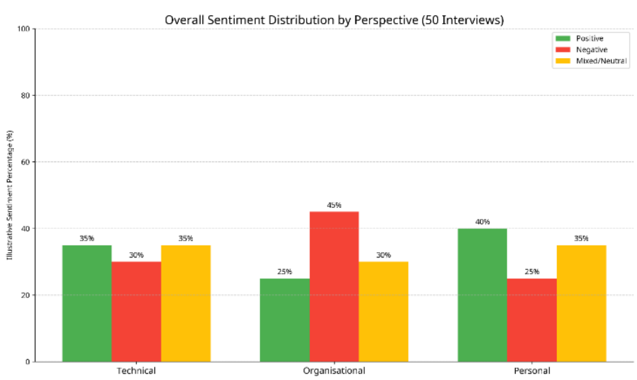

Fig. 4. Expressions of sentiments across TOP Perspectives

Personal sentiments include 40% positive expressions for accelerating benefits such as student engagement, faculty excitement, and creativity in solving societal problems. P24, from Qatar, praised the adoption of GenAI, saying, "*We found high levels of student engagement, motivation, and enthusiasm when working with GenAI technologies and projects*". An academic leader, P28 from Morocco, observed, "*Strong sense of purpose among faculty aiming to empower students with future-ready skills and develop ethical AI practitioners*". From Lebanon, P39 emphasised "*The positive impact of GenAI in fostering creativity and enabling students to address local and global challenges is significant*".

25% of the personal sentiments were negative, pointing out the need for continuous learning, the deterioration of students' critical thinking, and the anxiety about future jobs. For example, P45 from KSA expressed, "*All faculty are concerned about burnout due to the relentless demand for continuous learning and adaptation to new GenAI tools and pedagogical approaches*". Trying to address the negative impact on students, P1 reported the "Apprehension *regarding student over-reliance on AI tools, potentially hindering the development of critical thinking and fundamental problem-solving skills*". Such sentiments document the potential for GenAI to diminish human connection in education if not implemented thoughtfully and ethically.

25% of the personal sentiments were neutral and reflect the status quo of the trio faculty-management-student relationships. For example, P38 from Oman reported "*Faculty acknowledging the utility of GenAI tools for grading and coding assistance for managing workload, but also expressing caution about their pedagogical impact*". There were contradicting expressions about students' experience, such as "*A general sense of navigating uncharted territory, with both excitement for the possibilities and awareness of the responsibilities and potential pitfalls*", said P3 from Egypt.

Overall, the majority of the personal sentiments are either neutral or positive and address students' excitement, faculty dedication. However, it demonstrates that educators are tempered by concerns about workload, ethical development, and the potential for over-reliance on GenAI.

TABLE III
TRIANGULATION OF QUALITATIVE INTERVIEWS AND QUANTITATIVE SENTIMENT ANALYSIS

Perspective	What the Numbers Reveal	What the Interviews Confirm
Personal	High subjectivity shows deep emotion & nuance	Reflected in rich ethical debates and emotional statements
Technical	Mid-subjectivity shows evaluative complexity	Interviews blend tool benefits with cautionary tales
Organisational	Lower subjectivity shows structural focus	Interviews often describe policy, budgets, and curriculum

After a thorough analysis of the educators' sentiments, the readers can observe the triangulation between the qualitative narratives from the interviews and the quantitative analysis of sentiments. Table III explains how triangulation of both types of data led to a deeper understanding of the AI-powered CE educational ecosystem from TOP perspectives.

V. RESEARCH DISCUSSION

This section contrasts the conclusive findings with the literature remarks and leads to a final theoretical framework for the AI-powered Education Ecosystem for CE (or AI-EECE). The main highlights of this section are presented in Figure 5.

A. Technical Perspective of AI-EECE

This section covers the causality and resource-based view of GenAI's impact, benefits, and challenges in the context of CE.

In terms of the recognised *benefits* of adopting GenAI in CE, educators uniformly praised the learning-transformative capabilities of GenAI tools. Adaptive learning applications that utilise GenAI, intelligent tutoring applications, and instant feedback mechanisms have all emerged as dramatically enriching the learning process. The application of GenAI for generating and debugging computer codes (e.g., GitHub Copilot) was recognised as speeding up the students' work, with one professor finding it "*accelerates coding, shows students different ways to solve problems*". Simulation tools (e.g., MATLAB, Unity+AI, virtual labs) were also appreciated for giving access to secure, scalable, and low-cost experimentation facilities. As one interviewee put it, "*Our students now simulate robotic arms before going to the lab, reducing costs and increasing understanding*". The ability of GenAI to process rich data for learning analytics and predictive modelling was also a major advantage. Recent attempts to collect primary data about these benefits were published in conference proceedings such as Mellqvist & Mozelius (2024) and Zhang & Chang (2024). Yet, this is the first study that offers primary evidence on how GenAI improve CE across different functions at the course, programme, university, national, and international levels.

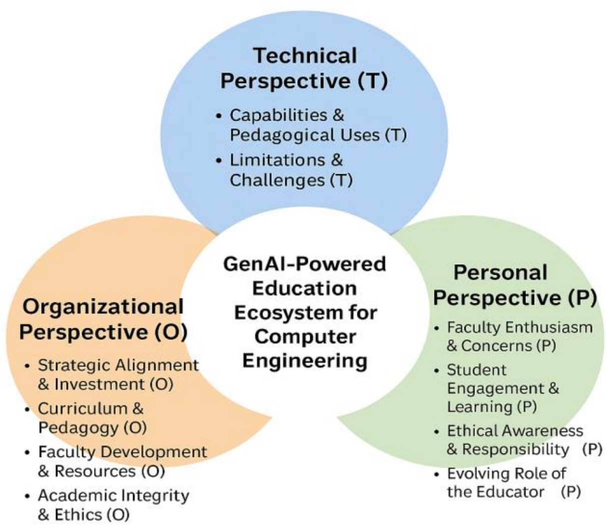

Fig. 5. Impact, benefits, and challenges of GenAI adoption in CE education

In terms of the recognised challenges of adopting GenAI in CE, educators reported a number of technical difficulties, such as students gaining a deep understanding of concepts rather than simply leveraging GenAI tools as a "*black box*". One faculty noted the challenge of making certain students "*know the underlying maths, not simply treat it as a black box*". It is challenging for CE educators that GenAI tools can be convincing, yet erroneous information (e.g., ChatGPT providing fake references for accurate information), which requires an emphasis on critical analysis skills. Also, the computational requirements for implementing certain sophisticated GenAI applications, such as training large models or executing complicated simulations, were presented as a challenge, especially in constrained resource settings. Availability of specialised hardware (e.g., GPUs) and stable, good-quality datasets, particularly for regional languages such as Arabic NLP, also became a technical challenge.

The literature was limited to the discussion of the general challenges faced in the higher education industry, such as Giannakos et.al (2024) and Camacho-Zuñiga et.al (2024), yet there is a need for primary research to address the CE education in terms of applications, tools, and policies.

B. Organisational Perspective of AI-EECE

In terms of benefits, CE educators and their institutions recognised the strategic importance of GenAI, leading to investments in GenAI tools, platforms, and infrastructure. Our findings also demonstrated the proactive role that many universities are developing policies for ethical GenAI use, academic integrity, and data privacy. The management's demand for agile curriculum review processes to incorporate GenAI-relevant topics and skills was heavily emphasised by CE educators as a key benefit to narrow down the industry-university gap. Both the interviews and sentiments reflect the need for university-industry to provide students with access to real-world GenAI tools and problems, and to align curricula with industry needs. P47, from Jordon, noted, "*The university encourages industry partnerships with GenAI's developers and entrepreneurs to assure continuous progression".* The use of cloud-based GenAI services was also seen as a way to potentially reduce infrastructure costs and improve accessibility.

In terms of challenges, resource misallocation is a major concern for educators and management due to the cost of GenAI software licenses (from freemium to subscription), hardware (needs for local servers and dedicated cloud), and maintenance, which can be prohibitive for some educators located in areas of political unrest. Keeping curricula and faculty skills up-to-date with the rapid pace of GenAI development is a continuous struggle.

For instance, P1, from KSA, mentioned that "*keeping the curriculum adaptable enough to reflect these changes is an ongoing concern*", while P7 added that "*helping teachers keep pace with cloud-based platforms is one of the more pressing issues for organisations*". It also seems evident that CE educators found the process of developing and implementing comprehensive, effective, and widely accepted policies on GenAI ethics and academic integrity is demanding and takes time and effort to build a national or international consensus. Ensuring equitable access to GenAI tools and resources across diverse student populations and institutional contexts (e.g., addressing low-bandwidth issues on rural campuses) is another critical organisational challenge.

C. *Personal Perspective of AI-EECE*

In terms of *benefits*, CE educators expressed their enthusiasm for the AI-powered transformation in their roles (course design, course delivery, student engagement, research and networking) that helps them become knowledge "facilitators rather than lecturers". This frees up time from repetitive tasks to focus on higher-order thinking and conceptual difficulties, such as having a patient and creating a technological solution to real-life problems. It seems that CE educators perceive GenAI as a tool to enhance student engagement and motivation. For example, P3, from Egypt, observed a "*spark in students when they build an image classifier that actually works*" The potential for GenAI to empower students, particularly early-stage researchers and those with disabilities, was highly valued. Drigas et.al (2016) documented the emergence of digital technologies to teach CE for students with special needs. But, yet the present study demonstrates how CE can use GenAI to tailor learning and provide personalised support to students who require extra support.

Another significant benefit expressed by P3, from Turkey, was feeling a "*renewed purpose*" and appreciating the cultural and linguistic relevance that can be achieved with GenAI tools, such as "*Fine-tuning LLMs in Arabic gives our students a stake in global tech*." Umanets et al. (2024) suggested that systemic AI training for CE educators could give a new purpose to more innovative pedagogies.

In terms of challenges, CE educators notice "*skill fade*" as a result of overreliance on GenAI tools and worry that students and academics create non-genuine outputs and deteriorate in their deep analytical skills. The learning curve for both faculty and students in adapting to new GenAI tools and pedagogical approaches can be steep. The adoption of GenAI creates biases, breaches of privacy, and poses a potential misuse by individuals. Such results add to the guidelines proposed in Moor (2020) to set ethics for GenAI-powered computers.

D. *Multiple Perspectives of AI-EECE*

This section discusses the final framework for AI-EECE. The TOP perspectives, as articulated in section 2, served as an analytical framework to structure the diverse experiences and observations of the interviewed educators. As proposed in section 2, the theoretical framework sets the educators-learners nexus at the core. *Educators* (Component 2) act as facilitators, designers, mentors, and co-learners. They engage with GenAI both as a pedagogical tool and as a research enabler that evolves over time. They play a critical role in guiding learners, shaping content, and modelling the responsible use of AI technologies. *Learners* (Component 1) are the primary stakeholders of the ecosystem, and they represent a diverse group with differing motivations and backgrounds. They adopt, upskill, and deploy GenAI tools to enhance their practical and academic development.

There is a dynamic educators-learners relationship that involves reciprocal feedback, collaborative learning, and iterative design processes. While these two groups are actors, GenAI tools and platforms (Component 4) are intermediate as actants (Gutiérrez, 2024). This *actant* is represented by digital infrastructure such as machine learning frameworks, cloud platforms, and intelligent tutoring systems.

This sociotechnical interaction creates unique components of the *Curriculum & Pedagogy* (Component 3), which define the content, learning objectives, assessment strategies, and ethical frameworks integrated into CE education. This element of the framework demonstrates how learners understand the implications of GenAI on society.

The *Institutional Environment* (Component 5) provides the organisational environment and institutional rules that enable this educational ecosystem. This includes policy frameworks, resource allocation, leadership support, academic regulations, and quality assurance mechanisms that shape how GenAI is integrated into university-level CE programmes.

The external environment includes two elements: *Regional & Global Context* (Component 6) *and Industry & Employers* (Component 7). The *regional and global context* captures the macro-level factors, including national GenAI strategies, cultural values, economic conditions, and global technological trends that were significant in the research findings. These factors set the strategic tone for GenAI adoption, influence ethical norms, and define the socioeconomic purpose of AI-EECE. The *industry and employers* create the demand for skill requirements, support applied research, provide internship opportunities, and help validate curricular relevance. Their input ensures that the ecosystem remains aligned with labour market needs and technological innovation (Mohamad, 2025; Awasthy et.al., 2020).

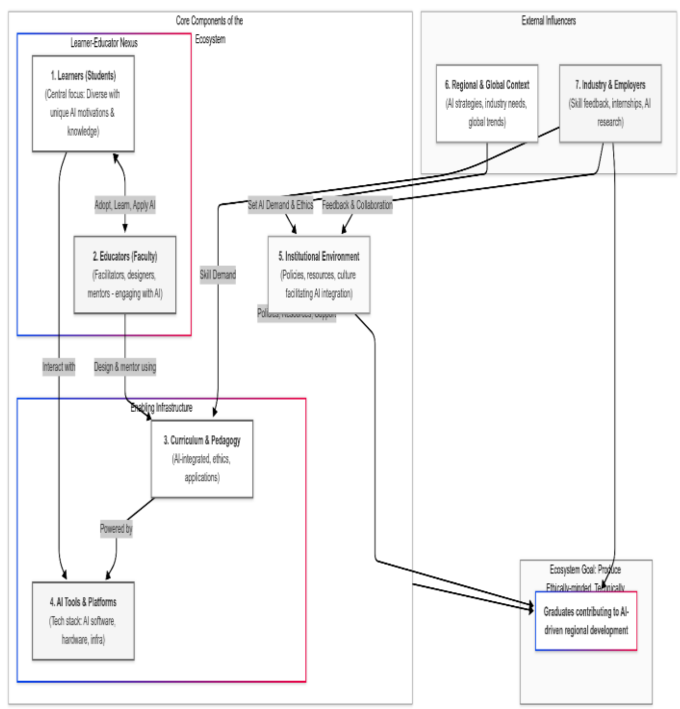

Fig. 6. GenAI-Powered Educational Ecosystem for CE

The *ecosystem dynamics and flow reflect the directional influences between the elements of the ecosystem (1-7).* Educators adopt GenAI tools and platforms to design instructional content and to mentor students in real-world application contexts. The *Curriculum and pedagogy* are generated by both educators and institutional frameworks. They need to be agile to accommodate new tools, ethical guidelines, and application-based learning. Students interact and learn from GenAI tools and platforms, and thus feed back into curriculum and policy development. Universities operate within the regional and global contexts to set their strategic priorities and ethics policies. Two lines present the outflow from *industry employers* who shape both the universities' strategies as well as the CE curriculum design to get job-ready graduates. Overall, these interconnections are represented in the lower-right box of the diagram to show the dynamic interplay between the elements of the ecosystem. It is also important to notice that CE graduates contribute to the regional development of GenAI's application, and they reshape the overall ecosystem in the long run via the development of human capital (Pochtovyuk et.al., 2020).

The complexity of the AI-EECE is examined through the TOP perspectives to achieve a holistic understanding of the above interconnections. The *technical* lens helps understand the functionality, performance, and suitability of the GenAI tools and platforms. It is essential to assess the quality and relevance of the GenAI infrastructure (Component 4) and to ensure that curriculum content (Component 3) reflects state-of-the-art technological capabilities. The technical perspective can also help examine the institutional routines (Component 5) regarding software and hardware investment.

The *organisational* lens of AI-EECE helps understand institutional structures, policies, and strategic frameworks in the ecosystem. It is essential to assess the role of the Institutional Environment (Component 5) in resourcing, planning, and quality assurance. In addition, it sheds light on how universities align their strategies with the national GenAI strategies and accreditation standards (Component 6). Also, addresses the university's agility to support innovation and respond to industry collaboration.

The *personal* lens of AI-EECE helps understand the individual's (educators & learners) values, motivations, and emotional experiences within the system. It addresses the human-centred view of CE educators, and they build GenAI confidence and are willing to innovate and become technically committed when they deploy such tools and platforms. It also helps understand the learners' motivations, engagement levels, and trust in GenAI-powered learning. Overall, it helps understand the cultural attitudes toward GenAI found in the broader regional context (Component 6). The adoption of the TOP perspective in AI-EECE demonstrates how technology adoption in CE education is deeply interwoven with human judgment, ethical reflection, and strategic foresight.

CONCLUSION

This paper articulates a systemic and context-sensitive understanding of GenAI integration in CE education. By accounting for technical capacity, organisational structure, and personal experience, it offers a framework that is both robust and adaptable and based on primary research from the MENA region. The final framework presented in Figure 6 could serve as an operational guideline for higher education institutions that prepare the next generation of CE professionals. They can use it to assess their current state, identify areas for intervention, and prioritise investments that support the long-term development of a resilient, ethical, and locally relevant GenAI workforce.

In practice, AI-EECE suggests agility for Curriculum Development and Pedagogy to recognise the rapid evolution of GenAI (from T perspective) and the need for interdisciplinary connections between AI ethics and societal applications (from O & P perspectives). The emerging pedagogical methods need to balance between GenAI proficiency (T) and critical thinking (O). The institutional *policymaking and strategic planning* need to be holistic by addressing technical infrastructure (T) and by providing sustained funding, agile governance structures, robust faculty support (O), and fostering an ethical and inclusive culture (O & P). The study results and the framework proposed guide CE faculty on how to develop a continuous, comprehensive professional development plan to integrate GenAI in teaching, learning, and research and how to navigate the ethical and personal dimensions of its use (O & P).

The scholarly community can also benefit from the final framework of AI-EECE because it extends existing literature on GenAI in higher education (Zawacki-Richter et al., 2019) and engineering education (Graham, 2018) by providing a more structured and empirically grounded multiple perspectives. While many studies focus on specific technical tools, pedagogical strategies, or ethical concerns in isolation (Selwyn, 2021; Boddington, 2023), this framework offers a cohesive structure for integrating these diverse elements. The application of Linstone and Mitroff's MPT to this specific domain, supported by extensive qualitative data and sentiment analysis, represents a novel contribution, offering deeper insights than studies with a singular perspective or limited empirical grounding, particularly within the studied regional context. This study suggests that the TOP perspective does not play in isolation; rather, they interplay to generate hybrid perspectives. Each hybrid would have a different level of complexity and would be proven by a different mix of positive, negative, or neutral sentiments.

REFERENCES

Acharya, D. B., Kuppan, K., & Divya, B. (2025). Agentic AI: Autonomous Intelligence for Complex Goals–A Comprehensive Survey. *IEEE Access*.

Awasthy, R., Flint, S., Sankarnarayana, R., & Jones, R. L. (2020). A framework to improve university–industry collaboration. *Journal of Industry-University Collaboration*, *2*(1), 49-62.

Bansal, T. (13th Oct 2023). Does OpenAI's Non-Profit Ownership Structure Actually Matter?. Forbes, Leadership Strategies. Available at: Does OpenAI's Non-Profit Ownership Structure Actually Matter? Accessed on 30th April 2025.

Boddington, P. (2023). AI ethics. *Singapur: Springer International Publishing*, 48.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77-101.

Bozkurt, A., Karadeniz, A., Baneres, D., Guerrero-Roldán, A. E., & Rodríguez, M. E. (2021). Artificial intelligence and reflections from educational landscape: A review of AI studies in half a century. *Sustainability*, *13*(2), 800.

Camacho-Zuñiga, C., Rodea-Sánchez, M. A., López, O. O., & Zavala, G. (2024, May). Generative AI Guidelines by/for Engineering Undergraduates. In *2024 IEEE Global Engineering Education Conference (EDUCON)* (pp. 1-8). IEEE.

Carter, L., Liu, D., & Cantrell, C. (2020). Exploring the intersection of the digital divide and artificial intelligence: A hermeneutic literature review. *AIS Transactions on Human-Computer Interaction*, *12*(4), 253-275.

Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry and research design: Choosing among five approaches* (4th ed.). Sage Publications.

Drigas, A., Pappas, M., & Lytras, M. (2016). Emerging technologies for ict based education for dyscalculia: Implications for computer engineering education. *International journal of engineering education*, *32*(4), 1604-1610.

Elish, M. C. (2019). Moral crumple zones: Cautionary tales in human-robot interaction (pre-print). *Engaging Science, Technology, and Society (pre-print)*.

Finnie-Ansley, J., Denny, P., Becker, B. A., Luxton-Reilly, A., & Prather, J. (2022, February). The robots are coming: Exploring the implications of openai codex on introductory programming. In *Proceedings of the 24th Australasian computing education conference* (pp. 10-19).

George, A. S. (2023). Preparing students for an AI-driven world: Rethinking curriculum and pedagogy in the age of artificial intelligence. *Partners Universal Innovative Research Publication*, *1*(2), 112-136.

Giannakos, M. N., Azevedo, R., Brusilovsky, P., Cukurova, M., Dimitriadis, Y., Hernández-Leo, D., Järvelä, S., Mavrikis, M., & Rienties, B. (2024). The promise and challenges of generative AI in education. *Behaviour & Information Technology*, 1–27. https://doi.org/10.1080/0144929x.2024.2394886

Gnanaprakasam, J., & Lourdusamy, R. (2024). The role of AI in automating grading: Enhancing feedback and efficiency. In *Artificial Intelligence and Education-Shaping the Future of Learning*. IntechOpen.

Graham, R. (2018). The global state of the art in engineering education. *Massachusetts Institute of Technology (MIT) Report, Massachusetts, USA*.

Gutiérrez, J. L. M. (2024). On actor-network theory and algorithms: ChatGPT and the new power relationships in the age of AI. *AI and Ethics*, *4*(4), 1071-1084.

Han, Y., & Moghaddam, M. (2021). Analysis of sentiment expressions for user-centered design. *Expert Systems with Applications*, *171*, 114604.

Linstone, H. A. (1999). *Decision Making for Technology Executives: Using Multiple Perspectives to Improved Performance*. Artech House.

Linstone, H. A. (2019). The Management of Technology: Old and New Perspectives. In *Natural Resources And Development In Arid Regions* (pp. 265-292). Routledge.

Linstone, H. A., & Mitroff, I. I. (1994). *The challenge of the 21st century: Managing technology and ourselves in a shrinking world*. Suny Press.

Lythreatis, S., Singh, S. K., & El-Kassar, A. N. (2022). The digital divide: A review and future research agenda. *Technological Forecasting and Social Change*, *175*, 121359.

Mellqvist, N., & Mozelius, P. (2024). Exploring Student Perspectives on Generative AI in Requirements Engineering Education. *Proceedings of the International Conference on AI Research.*, *4*(1), 473–481. https://doi.org/10.34190/icair.4.1.3136

Mills, J. E., & Treagust, D. F. (2003). Engineering education: Is problem-based or project-based learning the answer? *Australasian Journal of Engineering Education*, *3*(2), 2-16.

Ministry of State for Artificial Intelligence (MoSAI). AI Ethics Principles & Guidelines. Available at: MOCAI-AI-Ethics-EN-1.pdf [Accessed in 20th of March 2025].

MIT-Solan-Middel East. (2023) The Middle East Region is Preparing for a Future Tech Ecosystem. Available at: https://www.mitsloanme.com/article/the-middle-east-region-is-preparing-for-a-future-tech-ecosystem/ [Accessed in 4th of May 2025].

Mohamad, M. (2015). *Multiple Perspective of Mobile Money System Development: Action Case of e-Masary Wallet* (Doctoral dissertation, University of Manchester).

Mohamad, M. (2025). Technological Innovation Ecosystem for Sustainable Development: Multi-cases from Federal Universities in UAE. In Universities and the SDGs: Empowering Change in the MENA Region.

Mohamad, M., & Eldarmi, A. (2020). Activity theory as a lens for Corporate Managerial Innovation: A Proposed Systematic Framework for Military Managerial Innovation. Proceedings of the British Academy of Management. Available at: https://virtual.oxfordabstracts.com/event/1520/submission/671

Moor, J. H. (2020). What is computer ethics?. In *The ethics of information technologies* (pp. 15-24). Routledge.

Pardos, Z. A., & Dadu, A. (2020). Sentiment analysis of MOOC discussion forums: What it can tell us about the student experience. In *Proceedings of the Tenth International Conference on Learning Analytics & Knowledge* (pp. 442-451).

Phillips, F., & Linstone, H. (2016). Key ideas from a 25-year collaboration at technological forecasting & social change. *Technological Forecasting and Social Change*, *105*, 158-166.

Pochtovyuk, A., Buriak, I., Buriak, M., & Zakharova, O. (2020, September). High Engineering Education as a Component of the System of Human Capital Development. In *2020 IEEE Problems of Automated Electrodrive. Theory and Practice (PAEP)* (pp. 1-5). IEEE.

Popenici, S. A., & Kerr, S. (2017). Exploring the impact of artificial intelligence on teaching and learning in higher education. *Research and Practice in Technology Enhanced Learning*, *12*(1), 22.

Sahoo, K., Samal, A. K., Pramanik, J., & Pani, S. K. (2019). Exploratory data analysis using Python. *International Journal of Innovative Technology and Exploring Engineering*, *8*(12), 4727-4735.

Sailun, Z., & Alhajj, R. (2019). Sentiment analysis in education: A review. *Knowledge and Information Systems*, *60*(1), 1-31.

Selwyn, N. (2021). *Education and technology: Key issues and debates*. Bloomsbury Publishing.

Siemens, G., & Baker, R. S. D. (2012, April). Learning analytics and educational data mining: towards communication and collaboration. In *Proceedings of the 2nd international conference on learning analytics and knowledge* (pp. 252-254).

Somasundaram, M., Latha, P., & Pandian, S. S. (2020). Curriculum design using artificial intelligence (AI) back propagation method. *Procedia Computer Science*, *172*, 134-138.

Sottilare, R., & VanLehn, K. (2020). Intelligent tutoring systems swot analysis. *Design Recommendations for Intelligent Tutoring Systems*, *27*.

Umanets, V., Shakhina, I., & Rozputnia, B. (2024). Training future computer science teachers to use artificial intelligence technologies in the educational process. *Modern Information Technologies and Innovation Methodologies of Education in Professional Training Methodology Theory Experience Problems*, (72), 162-169.

Vassilakopoulou, P., & Hustad, E. (2023). Bridging digital divides: A literature review and research agenda for information systems research. *Information Systems Frontiers*, *25*(3), 955-969.

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education – where are the educators? *International Journal of Educational Technology in Higher Education*, *16*(1), 39.

Zhang, Z., & Chang, Y. (2024). Leveraging Generative AI to Enhance Engineering Education At Both Low-Level And High-Level Study. In *2024 Fall ASEE Mid-Atlantic Section Conference*.

VI. APPENDICES

Appendix 1: Python Coding for the interviewees' data

```
>>>
>>> # Step 1: Create a Pandas DataFrame from the raw data
>>> df = pd.DataFrame(raw_data)
Traceback (most recent call last):
  File "<python-input-5>", line 1, in <module>
    df = pd.DataFrame(raw_data)
         ^^
NameError: name 'pd' is not defined. Did you mean: 'id'?
>>>
>>> # Step 2: Extract and clean 'Speciality' and 'Educational Function'
>>> # This requires careful string manipulation based on your specific raw format.
>>> # For simplicity, I'll extract just the first part for 'Speciality'
>>> df['Speciality'] = df['Speciality_Raw'].apply(lambda x: x.split('B.Sc.')[0].strip().replace('M.Sc.', '').strip())
Traceback (most recent call last):
  File "<python-input-10>", line 1, in <module>
    df['Speciality'] = df['Speciality_Raw'].apply(lambda x: x.split('B.Sc.')[0].strip().replace('M.Sc.', '').strip())
                       ^^
NameError: name 'df' is not defined
>>> df['Educational Function'] = df['Educational_Function_Raw']
Traceback (most recent call last):
  File "<python-input-11>", line 1, in <module>
    df['Educational Function'] = df['Educational_Function_Raw']
                                 ^^
NameError: name 'df' is not defined
>>>
>>> # Step 3: Rename and select columns to match your desired output
>>> # Assuming 'Full_Name' is implicitly tied to Professor ID and not needed as a separate column
>>> df_reformatted = df[['ID', 'Country', 'Speciality', 'Educational Function', 'GenAI_Tools_Raw']].copy()
Traceback (most recent call last):
  File "<python-input-15>", line 1, in <module>
    df_reformatted = df[['ID', 'Country', 'Speciality', 'Educational Function', 'GenAI_Tools_Raw']].copy()
                     ^^
NameError: name 'df' is not defined
>>>
>>> # Step 4: Rename the GenAI_Tools_Raw column to 'GenAI Used in Education'
>>> df_reformatted.rename(columns={'ID': 'Professor ID', 'GenAI_Tools_Raw': 'GenAI Used in Education'}, inplace=True)
Traceback (most recent call last):
  File "<python-input-18>", line 1, in <module>
    df_reformatted.rename(columns={'ID': 'Professor ID', 'GenAI_Tools_Raw': 'GenAI Used in Education'}, inplace=True)
    ^^^^^^^^^^^^^^
NameError: name 'df_reformatted' is not defined
>>>
>>> # Step 5: (Optional) Further clean 'GenAI Used in Education' if needed
>>> # This might involve removing parenthetical information if it's too detailed,
>>> # or standardizing names.
>>> df_reformatted['GenAI Used in Education'] = df_reformatted['GenAI Used in Education'].str.replace(r'\(.*?\)', '', r\egex=True).str.strip()
Traceback (most recent call last):
```

Appendix 2: Coding for the sentiment analysis graphs

```
# Reload the document
doc_path = "/mnt/data/All interviews.docx"
doc = Document(doc_path)

# Extract interview blocks
interview_blocks = []
current_block = []
for para in doc.paragraphs:
    if para.text.strip() == '---' and current_block:
        interview_blocks.append('\n'.join(current_block))
        current_block = []
    elif para.text.strip():
        current_block.append(para.text.strip())

# Perform sentiment analysis
sentiments = []
for i, block in enumerate(interview_blocks):
    blob = TextBlob(block)
    polarity = blob.sentiment.polarity
    subjectivity = blob.sentiment.subjectivity
    sentiments.append({'Interview': i + 1, 'Polarity': polarity, 'Subjectivity': subjectivity})

# Create DataFrame
df_sentiments = pd.DataFrame(sentiments)

# Plot: Sentiment Polarity
plt.figure(figsize=(14, 6))
sns.barplot(x='Interview', y='Polarity', data=df_sentiments, palette='coolwarm')
plt.title('Sentiment Polarity Across Interviews')
plt.xlabel('Interview Number')
plt.ylabel('Polarity')
plt.xticks(rotation=90)
plt.tight_layout()
polarity_path = "/mnt/data/sentiment_polarity.png"
plt.savefig(polarity_path)
plt.close()

# Plot: Sentiment Subjectivity
plt.figure(figsize=(14, 6))
sns.barplot(x='Interview', y='Subjectivity', data=df_sentiments, palette='viridis')
plt.title('Sentiment Subjectivity Across Interviews')
plt.xlabel('Interview Number')
plt.ylabel('Subjectivity')
plt.xticks(rotation=90)
plt.tight_layout()
subjectivity_path = "/mnt/data/sentiment_subjectivity.png"
plt.savefig(subjectivity_path)
plt.close()

# Return paths for download
polarity_path, subjectivity_path
```

Appendix 3: Sentiment Analysis Table

A. Sentiment Polarity by Perspective

Perspective	**Avg. Polarity**
Technical	**0.088**
Organisational	**0.195**
Personal	**0.194**

B. Sentiment Subjectivity by Perspective

Perspective	**Avg. Subjectivity**
Technical	**0.488**
Organisational	**0.477**
Personal	**0.527**