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How can a Holistic Approach to Practice, Research and Policy for Sustainable Engineering Education be Developed? An Investigation

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Abstract

Context
In the last two decades, significant pedagogical advances aimed at enhancing the UK's engineering education have emerged. However, there's a noted absence of an integrated approach linking policy and practice to evidence-based research in this field.

Purpose or Goal
This study seeks to bridge this gap by exploring the lived experiences and perspectives of engineering education leaders who have been at the forefront of pioneering education reforms in the UK. It aims to understand the challenges they face and identify potential solutions and models that could address the evolving needs of undergraduate engineering education.

Methods
The study utilizes a qualitative research design with purposeful sampling. Qualitative data is obtained through interviews to gain in-depth insights into the experiences and perspectives of stakeholders. Thematic analysis of the collected data is used to identify common themes, patterns, and relationships.

Outcomes
The findings of this qualitative preliminary investigation are to develop research questions to inform and frame a more comprehensive quantitative study aimed at shedding light on the development of curriculum frameworks for implementing effective and scalable engineering education models in the UK.

Conclusion
This study reveals the conflicting and complementary factors in the UK engineering education landscape. This highlights the need for a systems-based approach connecting policy and practice, informed by evidence-based research for developing a sustainable engineering education framework in the UK.

Keywords—Engineering Education Reform; Sustainable Curriculum Innovation and Design; Integrated Engineering Education; Holistic Engineering Education, Systems Approach to Engineering Education.

I. INTRODUCTION

Undergraduate engineering education in the UK faces significant challenges in adapting to the 21st century (Jones et al., 2000 and Spinks et al., 2006). Since the turn of the century, there has been widespread agreement that reforms are urgently needed to prepare students for increasingly complex global issues (Graham, 2012 and Haghighi, 2005). The UK government, on its part, has implemented various policies to attract young people into engineering (Clark, 2011). Additionally, the accreditation of engineering degrees and chartered engineers by the Engineering Council and the various professional engineering institutions has ensured global standards and quality control (Levy, 2000). However, coordinated efforts through partnerships, policy, and research are required from universities, professional engineering institutions, government, and other stakeholders to guarantee meaningful and sustainable reforms in engineering education (Graham, 2012).

There have been ongoing reforms in UK engineering education over the past decade. These reforms have been highlighted by the Engineering Professors Council (EPC) and the Institution of Engineering Technology (IET) (EPC and IET, 2017), and in a report highlighting innovation and good practice in engineering education across the UK (EPC and IET, 2019). Collectively the reforms highlight how engineering educators in the UK are responding to the challenges and opportunities of the 21st century through innovation and reforms to engineering education practices and pedagogies. Examples of approaches discussed in these papers include reforms to curriculum design, assessment, teaching methods, student engagement, industry collaboration, use of state-of-the-art technology, and sharing good practices and lessons learned across the sector (Fowler et al, 2023).

Reaffirming the international standing of engineering education reforms by UK universities, University College London (UCL) and the University of Cambridge, have been identified as global leaders in engineering education alongside ten other universities, with UCL being further identified as an

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emerging leader alongside four other universities (Graham, 2018). Additionally, policy changes in higher education enacted in the Higher Education and Research Act 2017 (HERA) have enabled new providers such as the New Model in Technology and Engineering (NMITE), Dyson Institute of Engineering and Technology (DIET) and the Engineering & Design Institute London (TEDI-London) to establish new universities that focus on modern engineering pedagogies.

However, UK research in engineering education practice, although it is growing, is still limited and does not reflect the reform work that is being implemented. There is low engagement in engineering education research (EER) in the UK, evidenced by few publications, mostly single-author or single-institution (Nyamapfene, 2017), suggesting lack of collaboration between engineering education researchers and practitioners. With respect to policy, Cooper et al. (2023), have argued that UK engineering policy, unlike science policy, is rarely discussed or scrutinised in the academy or in public governance. The authors concluded that engineering is largely absent or marginalised in government ministries, committees, agencies, and public bodies.

It could be argued that one of the main reasons for this shortcoming is the lack of a holistic system in the UK that connects policy, and practice in undergraduate engineering education to evidence-based research, and that encompasses all stakeholders.By examining the interplay between these three elements of policy, practice and research, the study aims to identify strategies and frameworks that promote effective and scalable engineering education models. In this study we explore the lived experiences and perceptions of one group of stakeholders, namely engineering education changemakers, who have been at the forefront of pioneering engineering education reforms in the UK.

The goal is to help engineering educators enhance the adaptability, innovation, and preparedness of engineering graduates, enabling them to tackle complex challenges and contribute to societal development. However, limited research exists on the integration of policy, practice, and research as a cohesive paradigm to cultivate future-ready engineers. This study seeks to bridge that gap by exploring the synergistic relationship between policy, practice, and research and its impact on engineering education outcomes for designing effective learning ecosystems.

This preliminary investigative study is a component of a broader project focused on the following research questions.:

RQ1: What are the strategies and frameworks that promote effective and scalable engineering education models in the UK?

RQ2: How have current engineering education models enhanced the adaptability, innovative thinking, and work-readiness of engineering graduates in the UK?

RQ3: How has policy, practice and research in engineering education collectively influenced and contributed to the development of current engineering education models in the UK?

The objective of this qualitative preliminary investigation is to use these research questions to inform and frame a more comprehensive quantitative study that addresses these proposed questions in depth.

A. RQ1

Delved into the engineering educational model at the participants' respective Universities/Departments/Institutions. It sought to get an overview of the model, exploring its foundational principles, pedagogical approaches, and key components. Additionally, it sought to understand the driving forces behind the model's adoption or development, shedding light on the motivations that led to its implementation within participant's educational context. Finally, this research question sought to provide a comprehensive foundation for examining the subsequent research questions, offering insight into the model's impact and purpose within the participants' academic institutions.

B. RQ2

Focused on the tangible impacts of the engineering education models at participants' institutions. It examined how the model had positively influenced academic and employment outcomes for students. Furthermore, this research question investigated the evolution of engineering graduates in terms of their work-readiness, aptitude, and skills compared to earlier cohorts before the model's implementation, supported and justified by empirical evidence.

C. RQ3

Delved into the past influence of government policies and evolving engineering practices on the development of new engineering education models in the UK. It examined the extent to which these external factors influenced curriculum design and delivery, as well as the development of innovative educational models. Additionally, it investigated the degree to which these models were shaped by evidence-based research, shedding light on the research-informed nature of the educational approaches.

II METHODS

Qualitative data for this initial study is obtained through interviews with engineering leaders, educators, and industry professionals. The collected data is thematically analyzed to identify common themes, patterns, and relationships.

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A. Study Approach

Semi-structured, online interviews with engineering leaders, educators, and industry professionals were conducted on UCL MS Teams and/or Zoom, and timings were chosen to fit in with participants' availability. Online interviews were found to be most appropriate to this study, as our potential research participants are from different UK higher education institutions and arranging face-to-face interviews would be financially expensive and time-consuming.

B. Participant Selection

Following the approach by Graham (2018) in her study on the global state of the art in engineering education, we selectively engaged individuals known for their contributions to engineering education reforms in the UK. This purposeful sampling was guided by their contributions to their institutions and/or their impact in scholarship and research in engineering education. In selecting participants, we also considered diverse factors such as gender, ethnicity, institution types, leadership roles, personal and professional experiences, and the nature and scope of reforms they have implemented.

These individuals have on average 20 to 30 years' experience within the UK engineering higher education sector, and hence, collectively these interviews give us almost 200 to 300 years of experience and perspectives of the UK engineering higher education landscape. The research participants also have varied lengths of experience within the sector, and are at different hierarchies of leadership, which again, gives us insights from different hierarchical perspectives. The participants have all followed different career trajectories to their current positions, with some having non-engineering backgrounds such as Economics, Entrepreneurship and Design and Innovation. Some of the participants are established academics with strong technical research credentials, whilst others have come up through the education and management routes, and others have progressed from professional engineering practice to academia.

C. Positionality Statement

Regarding positionality, three of us have a technical engineering background, are currently education-focused academics within engineering, and collectively, we have led engineering educational reforms at six UK universities, five of which are research intensive institutions, and one a start-up engineering higher education institution. As educators and practitioners at the forefront of leading education reform, our positionality and background significantly shape our perspectives and approaches to this research. Collectively our breadth of experiences have exposed us to the complexities and challenges of implementing engineering education reforms in different higher education contexts.

Furthermore, we acknowledge and are aware that our background and training can impact the way we interpret data, engage with participants, and frame research questions. We are also cognisant of our positionality, potential biases, personal values, and beliefs, which include a strong commitment to embedding values and ethics in engineering education research and practise. While our values drive our passion for this research, we are self-conscious of the need to maintain objectivity and consider multiple perspectives throughout the research process.

To mitigate potential biases, we employ reflexivity and engage in continuous self-examination to incorporate diverse voices and viewpoints in our research, without seeking to impose our own voices and interpretations. We are committed to conducting a rigorous and ethical study that contributes to the ongoing dialogue on engineering education transformation in the UK.

D. Data Collection and Analysis

This study adheres to the ethical research guidelines established by the British Education Research Association (BERA, 2018). The research process is characterized by rigorous ethical considerations, starting with the acquisition of informed consent, which was obtained from all participants prior to conducting interviews. Participants were provided with detailed information about voice recordings and the assurance of their anonymity within the research. The interview sessions were conducted in a conversational manner, fostering a relaxed and open atmosphere, with participants displaying no signs of apprehension. Our approach employed semi-structured interviews, designed to delve deeply into the authentic experiences of the participants in relation to the research questions.

The interviews underwent thematic analysis. Each conversation was recorded and subsequently transcribed. The two researchers collectively analysed the transcripts to identify thematic categories that emerged organically from the participants' discussions. By posing similar questions to various participants across diverse data samples, we were able to shed light on common thematic concerns. These identified themes were then subjected to further examination through a review of existing literature, providing insights into how previous scholarship has addressed these issues.

III RESULTS AND DISCUSSIONS

All participants displayed a tendency to intermingle their responses, deviating from the specific research questions provided. They frequently initiated their answers to one question and proceeded to address additional questions from

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various research areas without prompting. This behavior was influenced by our interview style, characterized by an open-ended discussion approach. From the analysis of the interview transcripts, we identified ten emerging themes. Consequently, we have restructured this section, organizing the collective findings into subtopics that align with the emerging themes.

A. Driving Forces Behind Curriculum Transformation in Engineering Education: (RQ1, RQ2 and RQ3)

We identified several drivers and variables for engineering education reform as listed here:

1) Individual Visionaries vs. Institutional Initiatives

The study data suggests that curriculum transformation initiatives are primarily led by visionary individuals within most institutions who are passionate about change but face limited institutional buy-in.

2) Successful Funding Attraction

A participant from one of the engineering institutions succeeded in attracting significant funding for curriculum reform, and this helped to capture c the institution's leadership's attention and support.

3) Industry Influence

Industry-driven curriculum models aimed to shape engineers based on specific needs, feeling universities didn't align with their requirements.

4) Positive Impact of Policy Changes

Policy shifts permitting private institutions for targeted engineering needs benefited two of the engineering institutions by providing justification and funding for the desired engineering education reforms.

5) Institutional Imperative for Entrepreneurship

Some of the institutions integrated entrepreneurships into their engineering curricula with philanthropic or commercial support.

6) Bottom-Up, Passion-Driven Initiatives

Curriculum reforms frequently start with individual drive at the grassroots, as evidenced by one of the engineering institutions whose departmental evolution was spurred by the CDIO framework.

7) Unique Nature of Engineering Institutional Transformation

One of the engineering institution curriculum growths stemmed from its founder's vision and charisma. With funding and institutional backing, its distinct journey highlights a blend of factors not easily duplicated elsewhere.

In the landscape of engineering education, visionary individuals within institutions spearhead curriculum transformation, driven by passion and innovation. However, they often grapple with limited institutional support. This illustrates the dynamic interplay between individual visionaries and institutional initiatives in shaping engineering education.

B. Strategic Considerations for the Timely Implementation of Educational Reforms

Timely integration of educational reforms into an institution's culture is vital for enduring, significant changes:

1) Sustainability

Ensuring reforms' long-term viability is paramount. Extending implementation time helps deeply root new practices and minimizes superficial changes.

2) Cultural Shift

Educational modifications entail cultural transitions, necessitating sustained alignment efforts with the new vision.

3) Leadership Role

Leadership significantly influences reform pace, with figures like Engineering Institution 3's founder vital in championing change.

4) Experience Insights

Comparing institutions illuminates the diverse reform paths followed by individual institutions and offers insights for specific contexts.

5) Urgency vs. Sustainability

Balancing swift change with sustainable integration is key, considering potential resistance and momentum loss.

In conclusion, the timeframe for educational reforms should be carefully considered to ensure both sustainability and effective cultural integration. It's a delicate balance that requires leadership, adaptability, and a keen understanding of the institution's unique context. Learning from the experiences of different institutions can help inform the best approach for successful reform initiatives.

C. The Complex Challenges of Educational Reforms on Engineering Education Culture

The impact of educational reforms on the culture of engineering education is complex and multifaceted:

1) Sustained Recognition of Education-Focused Academics

Educational reforms have created pathways for the recognition and promotion of academics who excel in the domain of education. This recognition is a positive

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development, as it values teaching and pedagogical expertise alongside research, but there is no systemic and sustained implementation.

2) *Challenges in Cultural Shift*

Despite these positive changes, challenges remain in achieving a broader cultural shift in engineering education. Regulatory bodies, professional institutions, and councils may continue to prioritize traditional practices, which can hinder the full realization of a culture that values education as much as research.

3) Need for Alignment

Achieving a cultural shift requires alignment across all stakeholders in the field. This includes regulatory bodies, educational institutions, professional organizations, and industry. A collective effort is necessary to bring about a comprehensive transformation in the culture of engineering education.

4) Work in Progress

Cultural change often takes time and persistence. While progress has been made, it's important to recognize that the transformation of a long-established culture is an ongoing journey.

In summary, the impact of educational reforms on the culture of engineering education is a mixed bag of positive recognition and the persistence of traditional practices. To fully realize the desired cultural shift, it's essential for all stakeholders to work collaboratively and align their priorities with the evolving needs of engineering education in the modern era.

D. Multifaceted Outcomes of Educational Reforms

The insights from two participants', in particular offer a comprehensive view of the multifaceted outcomes of educational reforms. Here's a closer look at the key takeaways from their perspectives:

1) Employability and Industry Relevance

The study highlights the practical and industry-oriented aspects of educational reforms. For example, the reforms implemented at one of the institutions led to success in collaborating with industry in aligning education with workforce needs. This enhanced graduates' employability by making them more attractive to employers and better prepared for real-world challenges.

2) Learning Experience and Student Satisfaction

The study highlights that in addition to improving employability, engineering education reforms contribute to student contentment and educational quality. This, in turn, leads to improved student engagement and understanding, which can lead to more effective learning outcomes.

These two perspectives demonstrate that educational reforms can have a multi-dimensional impact, encompassing both employability and the overall educational experience. Successful reforms aim to strike a balance between preparing students for the workforce and providing them with a rewarding and effective learning journey. Ultimately, a well-rounded education aligns with the needs of both students and employers, creating a win-win scenario for all stakeholders.

E. Evolving Career Perspectives of Academics and the Value of Diverse Experiences

The recognition of leaders and engineering educators' expertise, as well as their mobility between institutions, can indeed be a positive outcome of educational reforms. When institutions value and acknowledge the contributions of these individuals, it can lead to increased opportunities for them to share their expertise and insights across various academic settings. This mobility not only benefits the educators but also enhances the exchange of innovative teaching methods, curriculum designs, and pedagogical approaches, ultimately contributing to the broader improvement of engineering education on a larger scale.

The career journeys of many participants' underscore the evolving perspective on career fluidity and the value of diverse experiences in academia and beyond. Here are some key takeaways from their trajectories:

1) Experience Diversity

Their careers emphasize the richness of diverse experiences, moving between academia, industry, and varied institutions.

2) Challenging Stereotypes

Their paths debunk the myth that startups harm careers, spotlighting how entrepreneurial ventures add value to academia and other fields.

3) Intersectional Career Recognition

The rise in acceptance of careers spanning sectors underscores that varied experiences fuel innovation.

4) Skill Transferability

Their moves highlight how skills from one setting can be valuable in another, leading to versatile academic and professional realms.

5) Change Adoption

Their trajectories underscore the essence of embracing varied career opportunities in today's fast-paced world.

In conclusion, the career paths of most of the participants' highlight the evolving nature of careers and the growing appreciation for interdisciplinary experiences. Their

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willingness to navigate between academia and other sectors enriches both their own professional development and the broader workforce and academic landscape.

F. Educational Leaders' Industry Background and Collaboration with Industry: Complex Dynamics

The observation that changes in educational institutions, apart from few institutions, do not have direct input from industry, despite the leaders often having a rich industry background, raises several important points:

1) Leaders' Lived Experiences

It's noted that the changes driven by these leaders are influenced by their personal experiences and insights gained from their industry backgrounds. Their understanding of industry needs and practices inform their decisions regarding educational reforms, even if industry is not formally involved.

2) Challenges of Non-Industry Experience

While industry experience are valuable, leaders without direct industry backgrounds often face challenges in working with industry partners. Bridging the gap between academia and industry can be complex, and leaders with industry experience may have an advantage in navigating this terrain.

3) Importance of Collaboration

Collaboration with industry is a crucial aspect of aligning education with workforce needs. While industry may not always be the driving force behind change, their input and collaboration can help ensure that educational reforms are relevant and responsive to industry demands.

The relationship between educational leaders' industry backgrounds and their ability to drive change in collaboration with industry is complex. While industry experience can be beneficial, the success of educational reforms often depends on effective collaboration between academia and industry, regardless of who initiates the changes.

G. Employer thoughts about current graduates

The feedback loop between employers and educational institutions regarding current graduates are challenging to establish and maintain consistently. Several factors contribute to this challenge:

1) Resource Constraints

Many educational institutions lack the necessary resources to implement and sustain continuous tracking and monitoring of graduates in the workforce. This includes financial constraints, limitations in data collection and analysis tools, and insufficient staff dedicated to alumni relations and career tracking.

2)Diverse Employer Views

Employers have varied expectations and criteria for evaluating graduates. This diversity can make it difficult to create a standardized feedback system that effectively captures the full range of employer perspectives.

3) Graduate Mobility

Graduates often move between jobs and even industries over their careers, making it challenging for institutions to track their progress consistently.

4*) Time Lag*

There can be a significant time lag between a graduate entering the workforce and any potential feedback from their employer, making it challenging to provide timely insights to educators.

Despite these challenges, establishing a feedback loop between educational institutions and employers is valuable for improving educational programs and ensuring graduates are well-prepared for the workforce. Efforts to overcome these challenges involve developing better data collection and analysis systems, fostering strong alumni networks, and building collaborative relationships with employers to facilitate ongoing communication and feedback.

H. Elevating Student Satisfaction: A Catalyst for Educational Reform Success

The participant perspective underscores the significance of student satisfaction as a pivotal factor in the success and widespread adoption of educational reforms. Here, we can further elaborate on the importance of this aspect:

1) Student-Centric Approach

Placing students at the centre of educational reforms is essential. By actively seeking their feedback and addressing their needs, institutions can tailor their reforms to provide a more engaging and effective learning experience.

2) Holistic Assessment

Student assessments should go beyond just measuring academic outcomes. Evaluating the broader educational goals, such as critical thinking and problem-solving skills, is crucial. This ensures that reforms align with the overarching objectives of education.

3) Continuous Improvement

Educational reforms should be viewed as an ongoing process. Regularly collecting and analysing student feedback allows institutions to identify areas for improvement and make necessary adjustments to enhance the learning experience continually.

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4) Model for Adoption

When educational reforms prioritize student satisfaction and holistic learning experiences, they can serve as a model for other departments or institutions seeking to implement similar changes. A successful approach in one context can inspire and guide reforms elsewhere.

5) Enhancing Competencies

Ultimately, the aim of educational reforms is not only to impart knowledge but also to equip students with essential skills and competencies that are valuable in their future careers and in life.

Focusing on student satisfaction and evaluating educational reforms from a generic learning perspective can lead to more effective, adaptable, and widely adopted improvements in education, benefiting both students and the institutions themselves.

I. Navigating the Transition from Startup to Operational Stability

The transition from the startup phase to the growth and operational stability phase is a critical juncture for many institutions and new departments, and it often requires a change in leadership and a shift in focus. Here's a deeper look at this transformation using Engineering Institution 3 as an example:

1) Changing Skill Requirements

In the early phase of growth, changemakers and/or founders prioritize entrepreneurial and innovative skills, driven by vision and a hands-on approach. As the institution expands, the focus shifts to management, scalability, and efficiency.

2) Leadership Transition

Knowing when to transition leadership is crucial. New leaders introduce expertise in strategic planning, fundraising, and organization. For many Engineering Institutions, a leadership change ushered in a new educational program perspective.

3) Reducing Dependency on Individuals

For institutional sustainability, reducing reliance on specific individuals is key. Establishing strong systems and processes ensures continuity and growth, independent of specific leaders, especially during transitions.

4) Promoting Vision Continuity

While leadership may change, it's essential to maintain the core vision and mission of the institution. A clear and shared vision can guide the institution through transitions and changes, ensuring that it stays true to its founding principles.

Transitioning from startup to growth requires understanding changing skill needs, introducing new leadership, and building systems for sustainability and continuity. This phase is pivotal for an institution's long-term success.

J. Navigating Complex Challenges in Engineering Education Policies

The issues highlighted regarding the policies and challenges in engineering and education in some regions are indeed complex and multifaceted:

1) Policy Fragmentation

The absence of cohesive and comprehensive policies can hinder the development and growth of education and engineering sectors. Fragmented policies make it difficult to establish a clear direction for educational institutions and can lead to inconsistency in quality and focus.

2) Political Use

Education and engineering are sometimes leveraged for political gain rather than being guided by a long-term strategic vision for the country. This can lead to policy decisions that prioritize short-term political interests over the broader needs of the education and engineering sectors.

3) Lack of Apex Body

The absence of a central governing body for engineering education can result in challenges related to standardization, quality control, and research coordination. A well-defined apex body can help set standards and drive improvements.

4) Funding Challenges

Adequate funding is crucial for research, development, and maintaining high-quality educational programs. The lack of consistent funding can create a "chicken and egg" situation where universities struggle to invest in research and innovation.

5) Policy Disconnect

There appears to be a gap between policy decisions and the real-world needs and challenges faced by educational institutions. The disconnect between policy and practice can hinder progress.

6) Lack of Collaboration

Collaborative efforts between universities and the government are essential for addressing these challenges. A coordinated approach can help advocate for change and drive policy reforms.

7) Respect for Universities

Universities and research institutions play a vital role in societal progress. A lack of political respect for these institutions can undermine their ability to contribute effectively to national development.

Addressing these issues requires a multi-faceted approach, including the development of comprehensive policies, fostering collaboration, and advocating for the importance of education and engineering in societal progress. It's crucial for stakeholders to work together to overcome these challenges and create a more conducive environment for education and engineering to thrive.

IV CONCLUSIONS

Mapping the above themes to a loop diagram as depicted in Fig. 1, the conflicting and complementary factors in this landscape operate in complex ways in the UK engineering education landscape and hence, there is a need for a concentrated systems-based approach to solve the issues. Findings from this study concur with Cooper (2023) that engineering policy has always been sidelined with respect to government policy. The issues raised by the engineering academics in this study echo findings from earlier papers (Davis, et al 2002) which indicated that an apex body had been set up to drive change within Higher Education, including engineering higher education. This was in the form of the Learning and Teaching Support Network (LTSN), which was set up in 2000, and which had an engineering subject centre that sought to address and drive change within engineering education across the UK. LTSN subsequently transformed into the Higher Education Academy, which, in turn merged with the Leadership Foundation for Higher Education and the Equality Challenge Unit in 2018 to form Advance Higher Education (HE), and the subject centre initiative was dismantled, negatively impacting collaboration on engineering education across the UK.

Therefore, we need a comprehensive agenda on advancing Engineering Education through critical exploration of engineering education policy, involving development of comparative data, rich descriptions of engineering education, research, and policy intersections, leveraging recent progress in engineering education, practice, sustainability, Equality, Diversity and Inclusion (EDI),and ethics, and establishing a central hub for engineering education policy-focused research. This framework, we hope would propel the comprehension and influence of engineering educations' role in policy realms.

Recommendations highlight critical areas for improvement in engineering education:

A. Consistent and Clear Policy

Establishing a consistent and clear policy framework for engineering education is crucial. This can provide guidance, standards, and a unified vision for the sector, ensuring that educational reforms align with broader national goals.

B. Adaptation of Regulatory Bodies and PEIs

Regulatory bodies and professional engineering institutions (PEIs) should be flexible and adaptable in response to new models and approaches to delivering education. This can help facilitate innovation and responsiveness to changing industry needs.

C. Structured Promotional Pathway for Educators

Creating a well-defined promotional pathway and recognition system for engineering educators can incentivize excellence in teaching and research. This can help attract and retain talented educators in the field.

D. Investment in Pedagogical Research

Increased investment in engineering education research is essential for advancing teaching methodologies, curriculum development, and educational outcomes. Research can drive evidence-based improvements in education.

E. Collaboration and Partnerships

Collaboration among universities, educators, and relevant stakeholders is crucial. Collaborative efforts can enhance the ability to secure funding, lobby for policy changes, and collectively address challenges in engineering education.

Implementing these recommendations can contribute to the development of a more robust and responsive engineering education ecosystem that aligns with the needs of industry and society while fostering excellence in teaching and research.

V FUTURE WORK

Considering the initial findings that correspond to complicated push-pull factors in the field, this work will build on the current investigation and expand by delving deeper into UK engineering education policy and the interplay between pedagogy, research, and practice. Studying the vital role of collaboration among diverse stakeholders will be key for the expansion and success of this project.

In addition to academia and government bodies, this initiative will seek to engage key stakeholders like Engineering Professional Councils (EPC), Royal Academy of Engineering, IEEE, IET and other relevant organizations to structurally address the challenging landscape of UK engineering education.

We aspire for this work to spark a robust discourse within the critical engineering community. In tandem with the authors' ongoing efforts to foster collaboration among engineering communities, we aim to cultivate a dynamic platform for the

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productive exchange and evolution of ideas in this space. By fostering partnerships and cooperation, this approach will aim to create a unified front in reshaping engineering education policy and practices, ensuring a sustainable and effective model that benefits both students and society at large.

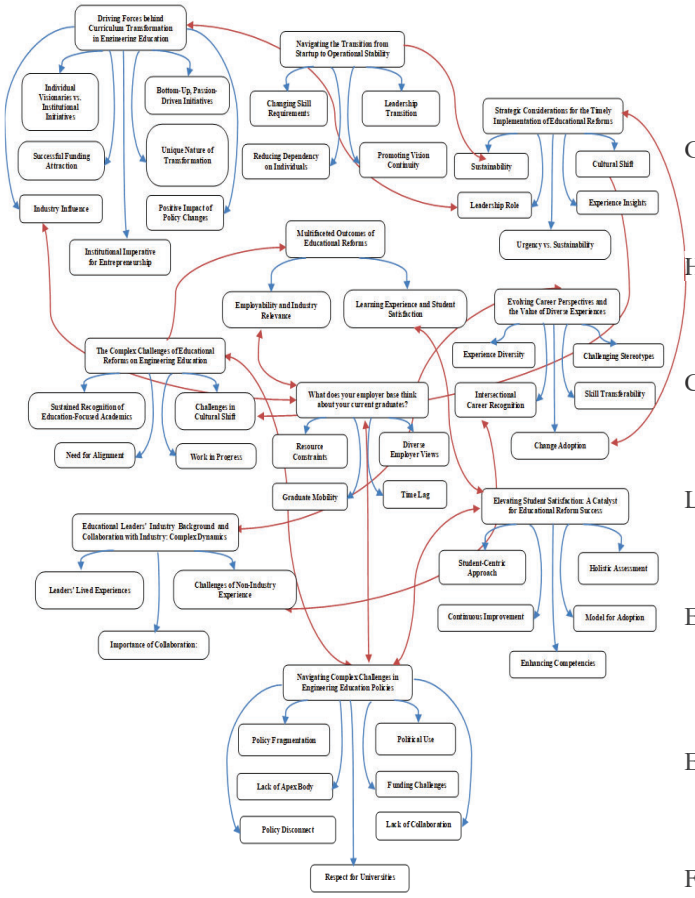

Fig. 1. Causal Loop Diagram Mapping Interactions at Play Between the Various Factors of Pedagogy, Policy, And Practice (red line signifies interconnection between the themes and blue lines within the themes) (adapted from An introductory systems thinking toolkit for civil servants - GOV.UK (www.gov.uk))

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