Enhancing Employability and Engagement in a Student-Centred Learning Environment: Insights from the MDX Internship Scheme

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***Abstract*— The higher education sector faces significant challenges, including the need to enhance student employability, engagement, and financial accessibility. Universities must equip graduates with both academic knowledge and practical skills while addressing financial barriers that hinder many students' progress. The MDX Internship Scheme, launched at Middlesex University in January 2024, responds to these challenges by offering paid, discipline-specific internships that integrate practical work experience with academic learning. The scheme enhances students' career readiness by enabling them to apply theoretical knowledge in real-world settings, develop essential skills such as teamwork and problem-solving, and build confidence through project achievements. Moreover, the internships alleviate financial burdens and foster a sense of belonging.**

This paper showcases the experiences of engineering undergraduates, postgraduates, and doctoral candidates, who participated in the MDX Internship scheme and undertook diverse projects spanning academic research, industry placements, and collaborations with local authorities, deepening their understanding of engineering and transferable skills. Local businesses also benefited from the scheme, gaining access to innovative student talent that positively influenced workplace dynamics and project outcomes, while building long-term partnerships with the university. The MDX Internship Scheme serves as a model for enhancing employability, engagement, and financial support in higher education.

Keywords—Engineering Education, STEM, Internships, Higher Education, Employability Skills, Transferable Skills

I. Introduction

The higher education landscape faces increasing pressure to address critical challenges, particularly in enhancing student employability, meaningful engagement, and financial accessibility. These challenges are exacerbated by the rapidly evolving demands of the global job market, where students are expected to graduate with not only theoretical knowledge but also practical skills and experience to succeed in the workforce [1][2]. Employers increasingly prioritise candidates who demonstrate workplace readiness, which includes technical expertise and soft skills such as adaptability, collaboration, and problem-solving [3]. However, financial and socio-economic barriers often limit students' access to these opportunities, disproportionately affecting those from underrepresented and disadvantaged backgrounds [1][3]. Factors such as the cost of living, unpaid internships, and limited networks exacerbate inequalities, reducing access to the professional experiences that are critical to employability [4].

In response, Middlesex University (MDX) has developed a comprehensive approach that includes not only an innovative internship programme but also a framework of eight graduate competencies[1]. These competencies, designed through extensive research and employer consultation, reflect the attitudes and behaviours required to thrive in an increasingly complex and dynamic professional environment. They include *leadership and influence; entrepreneurship; communication, empathy, and inclusion; curiosity and learning; collaborative innovation; resilience and adaptability; technological agility; and problem-solving and delivery.* This framework ensures that every MDX graduate is equipped with the knowledge, experience, reflective capacity, and confidence to articulate their capabilities, aligning their personal and professional development with the demands of the future world of work.

Internship programmes have emerged as a crucial intervention to bridge the gap between academic learning and workplace readiness. Research has shown that they significantly enhance students' employability by providing hands-on experience, improving practical skills, and integrating theoretical concepts with real-world applications [2][4][5]. For Science, Technology, Engineering, and Mathematics (STEM) students, internships also foster confidence and professional identity, preparing them for careers in high-demand fields. However, persistent challenges remain, including unequal access to internships for marginalised groups, misalignment with industry requirements, and the prevalence of unpaid or underpaid positions [2][4]. Universities, especially those serving diverse and economically challenged populations, are increasingly tasked with forming strategic partnerships with industries to address these gaps and align student skills with labour market demands [3].

The MDX Internship Scheme, launched in 2024, represents an innovative response by offering paid, discipline-specific placements that integrate theoretical concepts with

[1] MDX Graduate Competencies: https://www.mdx.ac.uk/news/2023/6/graduate-competencies-project-graduation-week/

TABLE I. OVERVIEW OF RELEVANT LITERATURE

Internship Model	Ref.	Target Audience	Key Features	Benefits	Challenges
Traditional Internships	[6][11]	General student population	Routine, task-based learning; typically aligned with academic credits	Basic industry exposure; development of workplace norms and soft skills	Limited innovation and skill depth; often lacks structured learning goals
Research-Oriented Models	[12][10]	STEM students; research-focused roles	Integration of structured frameworks like CURE (Course-Based Undergraduate Research Experience) and OBE (Outcomes-Based Education)	Enhanced technical skills, research competencies, and problem-solving abilities; better preparation for academic and industry roles	Resource-intensive; steep learning curve
Pre-Internship Programmes	[13]	Undergraduate students preparing for industry	Training sessions to develop soft skills, technical readiness, and workplace ethics before internships	Students enter internships better prepared; improved confidence and initial performance	Requires additional resources and time commitment from institutions
Context-Specific Programmes	[7][14]	Racially minoritised and underrepresented students	Tailored to underrepresented groups; focuses on inclusion, diversity, and vocational identity	Promotes equity and inclusivity; builds sense of belonging and career readiness	Scalability issues; limited to specific demographics
Outcome-Driven Models	[11][12]	All students seeking structured internships.	Clearly defined learning objectives; frequent assessment of skills against predetermined outcomes	Holistic skill development; ensures alignment with academic and industry goals	Requires significant planning and coordination
Industry-Specific Internships	[8][11]	Students in specific fields	Focused on sector-specific skills and knowledge (e.g., energy, manufacturing, IT)	High relevance to job roles; industry alignment enhances employability	Narrow applicability; requires industry partnerships
Short-Term Immersive Programmes	[14][15]	Students with limited availability	Brief but intensive internships; focus on rapid skill acquisition and exposure to industry	Allows participation without long-term commitment; ideal for skill sampling	Limited depth of learning; may lack follow-up opportunities
Integrated Internship-Education Modules	[11][15]	Upper-division undergraduates	Curriculum integrates internship experiences into academic learning	Promotes reflection on practical applications; enhances relevance of academic content	Complexity in curriculum design; requires collaboration between academic and industry mentors
Social Responsibility-Focused Internships	[9][15]	Engineering and sustainability students	Designed to develop awareness of societal and environmental impacts of work	Enhances ethical and social awareness; encourages engagement with sustainability and diversity	Often seen as secondary to technical training; challenges in measuring impact

practical experience. Beyond addressing financial barriers through internships, the scheme also facilitates the application and development of these graduate competencies in real-world settings. The scheme also facilitates university-industry collaborations, strengthening community ties and ensuring long-term benefits for both students and local businesses [3].

This paper explores the intersection of the MDX graduate competencies with STEM-specific skills, the Sustainable Development Goals (SDG), and the transformative Industry 5.0 goals that aim to prepare graduates for a sustainable, human-centric, and technologically advanced future.

Through an analysis of the experiences of STEM students participating in the MDX Internship Scheme and feedback from local businesses, the study aims to provide insights into how structured, competency-driven internships can serve as a model for fostering inclusive, practice-oriented learning environments. This approach highlights how such initiatives prepare graduates not only to meet the challenges of the modern workforce but also to contribute meaningfully to the sustainable and technological transformation of industries.

This paper is organised as follows. Section II presents a comprehensive literature review. Section III addresses the STEM graduate competencies. Section IV introduces the methodology, results analysis and discussions. Section V compiles a set of recommendations. Finally, Section VI summarises the conclusions.

II. LITERATURE REVIEW

Internship programmes have become a pivotal element in bridging the gap between academic learning and the demands of the professional world. They play a critical role in equipping students with the technical, professional, and socio-emotional skills required for employability, particularly in STEM fields. This literature review explores various models of internships, their significance, challenges, and outcomes, with a focus on how they enhance student employability, engagement, and preparedness for the evolving workforce.

A systematic methodology was adopted to select relevant literature for this study. Scholarly databases, including IEEE Xplore, Scopus, and Google Scholar, were searched using keywords such as “STEM internships”, “graduate competencies”, “Industry 5.0”, and “sustainability in education”. Articles were filtered for relevance based on their abstract and only peer-reviewed journal articles, conference papers, and systematic reviews were included.

Internships are widely recognised as a high-impact practice that fosters practical knowledge, workforce readiness, and career development [6][7]. They allow students to integrate theoretical knowledge with real-world applications, offering exposure to workplace dynamics, team collaboration, and problem-solving. Additionally, internships help students build vocational identity and enhance their confidence in addressing complex challenges [7] [8]. They also contribute to students' ethical and social awareness, particularly in fields like engineering, where societal responsibility is a growing concern [9][10].

The literature highlights several models of internship programmes, some with overlapping characteristics. However, we have identified below the four main models that might have distinct goals and outcomes:

- *Traditional Internship Models:* These focus on task-based learning and provide students with basic industry exposure. While they are effective in familiarising

TABLE II. COMPETENCIES MAPPING

UNESCO Competency	MDX Graduate Competency	Rationale
Systems Thinking	Problem Solving and Delivery, Curiosity and Learning	Recognises relationships and addresses uncertainty in systems.
Anticipatory	Resilience and Adaptability, Entrepreneurship	Envisions futures and evaluates potential risks and opportunities.
Normative	Communication, Empathy, and Inclusion, Leadership and Influence	Reflects on norms, values, and ethical decisions.
Strategic	Collaborative Innovation, Leadership and Influence	Implements collective, innovative actions for sustainability.
Collaboration	Collaborative Innovation, Communication, Empathy, and Inclusion	Promotes teamwork and participatory solutions.
Critical Thinking	Curiosity and Learning, Resilience and Adaptability	Encourages questioning and reflecting on sustainability practices.
Self-Awareness	Resilience and Adaptability, Leadership and Influence	Develops reflective thinking and personal motivation for sustainability.
Integrated-Problem Solving	Problem Solving and Delivery, Technological Agility	Addresses complex sustainability issues with interdisciplinary solutions.

students with workplace norms, they often lack depth in fostering innovation and advanced skills [6] [11].

- *Research-Oriented Models:* Emerging frameworks, such as the Outcomes-Directed Research Internship Model (ODRIM), combine structured research methodologies with experiential learning. These programmes have shown significant success in enhancing students' research capabilities, technical expertise, and teamwork [10][12].
- *Pre-Internship Training:* Pre-internship programmes aim to prepare students for the demands of industry by focusing on soft skills, technical readiness, and workplace ethics. These initiatives ensure students enter internships better equipped to succeed [13] .
- *Context-Specific Programmes:* Tailored internships for underrepresented groups, such as the National Action Council for Minorities in Engineering (NACME) Corporate Scholars Programme, focus on addressing barriers to inclusion and fostering vocational identity. These programmes promote diversity in STEM fields while building a sense of belonging for racially minoritised students [7][14].

The literature suggests that internship programmes contribute significantly to students' employability by providing practical, hands-on experience that aligns with industry expectations. Some of the benefits include:

- Enhanced Employability Skills: Internships develop critical skills, including problem-solving, communication, teamwork, and technical proficiency [6][11].
- Professional Identity Formation: They help students understand professional roles, responsibilities, and ethical considerations[9][10].
- Career Readiness: By exposing students to real-world challenges, internships prepare them for smooth transitions into the workforce, fostering adaptability and resilience[7][13].

However, despite their benefits, internship programmes face several challenges:

- Inequality in Access: Socio-economic barriers and a lack of opportunities for underrepresented groups limit the impact of internships [7][14].
- Alignment Issues: Many programmes struggle to align with industry expectations and academic outcomes, reducing their effectiveness in preparing students for specific job roles [11][12].
- Resource Intensity: Designing and implementing structured, outcome-driven internships require significant resources, limiting scalability [13][12].

Internships are increasingly being linked with specific employability competencies, such as critical thinking, leadership, and technological agility, which are essential in the Industry 5.0 era. These competencies align with the broader goals of sustainable development and the need for human-centric, innovative solutions [9][15]. Research-oriented internships, in particular, have shown success in embedding these competencies through structured learning and reflective practices [12].

Internship programmes, particularly when designed with structured frameworks and inclusive objectives, provide a robust platform for student skill development. However, to maximise their impact, it is essential to address challenges related to accessibility, alignment with industry needs, and integration with academic curricula. Research-oriented and context-specific models provide promising pathways to address these gaps while aligning with global goals such as the SDGs and Industry 5.0. Future research should focus on refining internship models and expanding their reach to underrepresented demographics, ensuring equitable and transformative educational opportunities.

Table I summarises key characteristics, benefits, and limitations of various internship approaches found in the literature.

III. STEM Graduate Competencies

Graduate competencies have emerged as a critical area of focus in bridging the gap between academic preparation and workforce demands. These competencies encompass the technical, professional, and socio-emotional skills that STEM graduates require to address complex global challenges, contribute to innovation, and thrive in diverse environments. The current literature emphasises their essential role in fostering sustainability, enhancing employability, and preparing students for dynamic and interdisciplinary professional contexts [16][17].

One consistent theme across the literature is the global perspective inherent in many competency frameworks. United Nations Educational, Scientific, and Cultural Organisation (UNESCO) sustainable competencies [18], for instance, stress critical thinking, systems thinking, and anticipatory skills as foundational for tackling interdisciplinary challenges in an interconnected world. These competencies align closely with

TABLE III. MDX GRADUATE COMPETENCIES – SDGs ALIGNMENT

MDX Graduate Competency	Supported SDGs	Focus Areas
Leadership and Influence	SDG 4 – Quality Education SDG 5 – Gender Equality SDG 16 – Peace, Justice, and Strong Institutions	Drives inclusive decision-making, ethical reflection, and collective action in leadership roles.
Entrepreneurship	SDG 1 – No Poverty SDG 8 – Decent Work and Economic Growth SDG 9 – Industry, Innovation, and Infrastructure	Envisions desirable futures and delivers innovative, sustainable solutions to global challenges.
Communication, Empathy, Inclusion	SDG 5 – Gender Equality SDG 10 – Reduced Inequalities SDG 17 – Partnership for the Goals	Enhances understanding, empathy, and teamwork to address disparities and build partnerships.
Curiosity and Learning	SDG 4 – Quality Education SDG 12 – Responsible Consumption and Production SDG 13 – Climate Action	Encourages exploration and questioning to address complex systems and sustainability issues.
Collaborative Innovation	SDG 9 – Industry, Innovation, and Infrastructure SDG 11 – Sustainable Cities and Communities SDG 17 - Partnerships for the Goals	Fosters teamwork and innovative solutions for sustainability challenges in communities.
Resilience and Adaptability	SDG 3 – Good Health and Wellbeing SDG 11 – Sustainable Cities and Communities SDG 13 – Climate Action	Builds flexibility and preparedness to address changing environmental, social, and technological landscapes.
Technological Agility	SDG 4 – Quality Education SDG 7 – Affordable and Clean Energy SDG 9 – Industry, Innovation, and Infrastructure	Uses advanced tools and systems to solve interdisciplinary sustainability problems.
Problem Solving and Delivery	SDG 6 – Clean Water and Sanitation SDG 12 – Responsible Consumption and Production SDG 15 – Life on Land	Delivers practical, interdisciplinary solutions for global challenges in water, waste, and biodiversity.

the UN SDGs, which emphasise the need for graduates to act for collective wellbeing and sustainability [19][17]. Similarly, the Organisation for Economic Cooperation and Development (OECD) global competence model integrates intercultural communication and global awareness with sustainability efforts, reflecting the demands of a workforce increasingly shaped by globalisation [19][18].

Although technical expertise remains central to STEM education, the importance of soft skills cannot be overstated. Employers have consistently identified deficits in teamwork, leadership, and communication among STEM graduates, presenting a significant barrier to their employability and workplace effectiveness [20][17]. These gaps highlight the need for enhanced collaboration between higher education institutions and employers to address critical competency shortages. Frameworks such as the National Association of Colleges and Employers (NACE) career readiness competencies, which include communication, teamwork, leadership, and technology, have been instrumental in defining the essential skills required for modern employment [17].

The Assessment of Transversal Skills in STEM (ATS STEM) conceptual framework [16] provides another comprehensive model for competency development, integrating problem-solving, meta-cognitive skills, collaboration, and disciplinary knowledge to support interdisciplinary learning. This framework aligns with broader global competency initiatives, such as UNESCO's, by emphasising the importance of systems thinking and interdisciplinary approaches to addressing sustainability challenges [18].

Effective competency development in STEM education requires innovative educational strategies. Work-Related Experiential Activities (WREAs), including internships and cooperative education programmes, have demonstrated their value in preparing students for the transition to the workforce [17]. These experiences help students refine critical competencies such as professionalism, communication, and leadership, while also providing real-world applications of their academic learning [20]. Moreover, interdisciplinary learning models that incorporate open-ended problems and collaborative projects foster critical thinking and encourage students to engage with complex, real-world issues [21][22].

Global mobility programmes, such as Erasmus, further enhance graduate competencies by providing opportunities for intercultural learning and exposure to diverse professional contexts. These experiences equip students to navigate multicultural work environments and develop global competence, an increasingly important skill in today's interconnected world [19][18]. However, challenges such as limited accessibility and scalability of these programmes remain, necessitating increased institutional and policy support.

Competency frameworks also increasingly align with the SDGs to ensure that graduates can contribute to addressing global challenges such as clean energy (SDG 7), sustainable

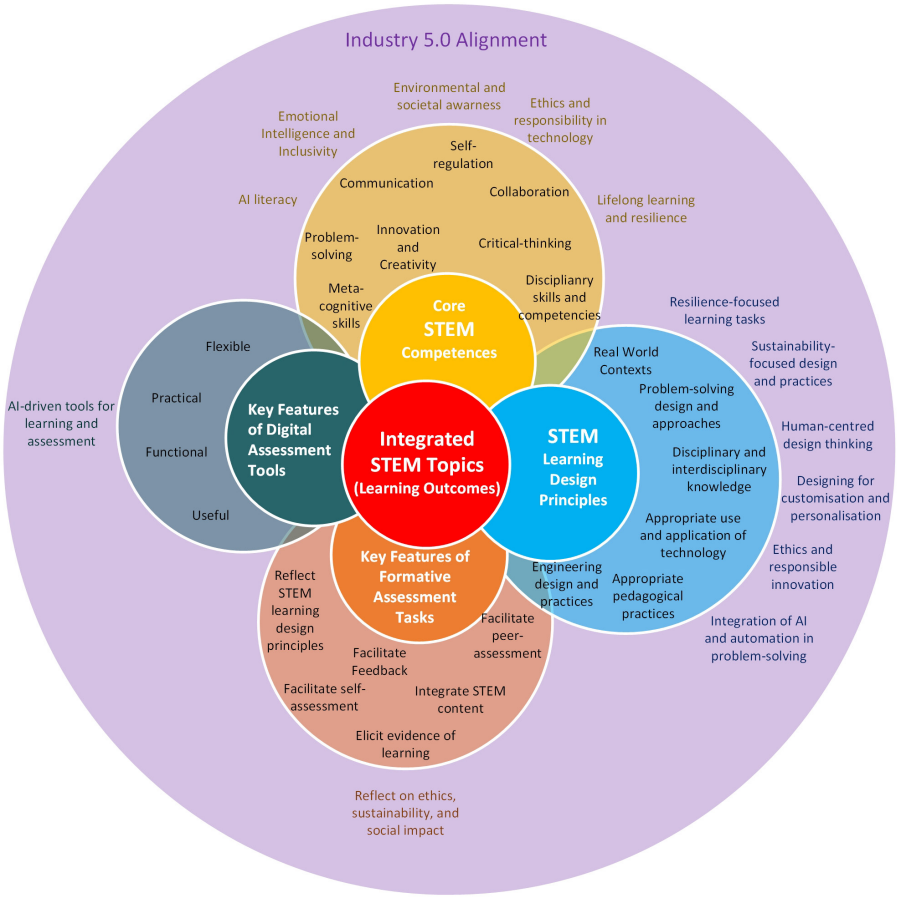

Fig 1. Proposed integrated STEM framework for Industry 5.0

cities (SDG 11), and climate action (SDG 13) [18]. For instance, UNESCO's framework emphasises integrating sustainability into curricula through interdisciplinary projects and problem-solving approaches that incorporate ethical and social considerations [18]. Table II demonstrates how the MDX graduate competencies align with the UNESCO sustainability competencies for education. The mapping shows which MDX competencies naturally correspond to the eight UNESCO competencies for sustainability and identifies areas of alignment. Both frameworks emphasise critical thinking, adaptability, collaboration, and innovation to foster sustainability-oriented graduates.

Furthermore, the MDX graduate competencies align with the SDGs by fostering the skills, attitudes, and knowledge necessary to address global challenges. Table III presents a detailed mapping of how the eight MDX graduate competencies support specific SDGs.

This analysis underscore the importance of comprehensive approaches to graduate competency development in STEM fields. Aligning educational frameworks with global standards such as UNESCO's sustainable competencies and the SDGs, embedding real-world contexts into learning, and addressing soft skill gaps through collaboration between academia and industry are crucial steps. These efforts are essential for preparing graduates to navigate a rapidly changing professional landscape while contributing meaningfully to global sustainability and innovation [20][17][18].

Furthermore, the ATS STEM framework [16] provides a holistic approach to integrated STEM education by combining eight core competencies: problem-solving, innovation and creativity, communication, critical thinking, meta-cognitive skills, collaboration, self-regulation, and disciplinary competences. It emphasises interdisciplinary learning through problem-solving, real-world applications, engineering design, and inquiry-based pedagogies. The framework incorporates formative assessments and digital tools to enhance learning by providing actionable feedback and fostering self-reflection. Designed to align STEM education with real-world challenges and workforce demands, the framework equips educators to deliver cohesive curricula that prepare students with the transversal skills necessary for innovation, sustainability, and adaptability in a globalised, technology-driven world [16].

In the context of Industry 5.0, STEM education must prepare graduates with a blend of technical and human-centric competencies to align with the evolving demands of workplaces and societal expectations. The core competencies identified include problem-solving, critical thinking, communication, and teamwork, underpinned by a focus on sustainability, ethical behaviour, and technological fluency [23]. Industry 5.0 emphasises the integration of humans and machines, highlighting the need for interpersonal skills, decision-making, and lifelong learning, alongside mastery of cutting-edge technologies such as artificial intelligence, Internet of Things (IoT), and robotics.

Educational environments must adopt innovative methods, such as project-based and inquiry-driven learning, to foster these competencies. Interdisciplinary collaboration, ethical and sustainable decision-making, and the ability to navigate complex systems are crucial for addressing global challenges. Moreover, embedding digital tools and adaptive learning technologies into curricula ensures students develop both technical expertise and the soft skills necessary for resilience and adaptability in dynamic industrial landscapes. Industry 5.0 thus calls for a balanced approach, where human

TABLE IV. STEM INTERNSHIPS OVERVIEW

Intern	Level of study	Internship Name/Role	Department/Research Groups/Centres
Intern 1	Year 2 Undergraduate	Campus Digital Twin	Estates – Middlesex University
Intern 2	PhD student	Curriculum Co-Creation for Embedding UNSDGs & Climate Framework into Education	Pedagogic Research Group
Intern 3	Postgraduate	Creating a sustainable workplace - occupants' behaviour impact case study	Barnet Council office
Intern 4	Year 3 Undergraduate	Changing the culture in STEM	Design Engineering and Mathematics Department
Intern 5	Recent Undergraduate finalist	Digital Twins for Cyber Physical Systems	London Digital Twin Research Centre
Intern 6	Year 3 Undergraduate	Technical Mechatronics Lab Assistant	Design Engineering and Mathematics Department
Intern 7	Postgraduate	Technical Robotics Lab Assistant	Design Engineering and Mathematics Department
Intern 8	Postgraduate	DigIT Project Intern	London Digital Twin Research Centre

values, sustainability, and advanced technological proficiencies converge to shape the next generation of engineers and technologists.

Consequently, in Fig. 1, we propose an enhanced version of the ATS STEM framework that reflects a forward-thinking approach to education, equipping students with the competencies and perspectives necessary to lead in a world shaped by Industry 5.0. The aim of the enhanced integrated STEM education framework is to ensure that STEM graduates are not only proficient in their technical fields but also prepared to address complex societal and environmental challenges. Thus, the proposed enhanced ATS STEM framework is designed to align with the principles of Industry 5.0 by integrating human-centric, sustainable, and technologically advanced competencies into STEM education. Building on the original ATS STEM structure [16], this framework emphasises ethical responsibility, environmental awareness, and emotional intelligence alongside technical expertise. Key additions include competencies such as human-machine collaboration, which equips students to work effectively with AI and automation, and sustainability-focused thinking, which prepares them to address global environmental challenges. The framework also introduces resilience-focused learning tasks, fostering adaptability in the face of rapid technological and societal changes. In terms of learning design, the framework shifts from purely technical solutions to human-centred design practices, ensuring that innovation prioritises user well-being and inclusivity. Assessment methods are enhanced with AI-driven tools for personalised feedback and the evaluation of ethical reasoning and sustainability in student projects. By embedding these features, the framework addresses the evolving demands of Industry 5.0, where technological advancements must coexist with ethical considerations, sustainability, and a focus on societal wellbeing. This approach ensures that STEM graduates are not only technically proficient but also equipped to lead responsibly in a globalised, rapidly changing world.

IV. Methodology, Results, and Discussions

This section gives an overview of the wider MDX Internship Scheme and presents the reflections provided by some STEM interns only. We further align their experiences from the internship to the competencies gained.

A. Research Questions

This study is guided by the following research questions:

- How structured internships enhance STEM students' employability by aligning academic knowledge with industry requirements?
- What competencies are most effective developed through the MDX Internship Scheme and how do these align with Industry 5.0 and Sustainable Development Goals (SDGs)?
- What challenges and barriers (e.g., socio-economic or gender inequalities) impact students' participation in internships, and how can these be addressed to ensure inclusivity?

B. MDX Internship Scheme

In January 2024, Middlesex University launched the MDX Internship Scheme, offering 59 on-campus work experience opportunities to students. Managed through Unitemps, the University's employability service, all positions were remunerated at the London Living Wage. This initiative allowed students to gain valuable, discipline-specific work experience by contributing to impactful projects across the University. Roles spanned a variety of disciplines, including Research and Laboratory Assistants, Music, Radio, and Video Producers, Marketing and Communications Interns, Photographers, Data Analysts, etc. These internships enabled students to apply their academic knowledge and skills in meaningful, professional contexts, supporting the work of both Faculties and Professional Services.

The scheme supported a diverse cohort, comprising 41 undergraduate and 18 postgraduate students, including 42 current international students, 7 students with EU or pre-settled status, and 10 British students. Gender representation included 34 female and 25 male participants. Collectively, student interns earned £50,000 in wages by the end of August 2024, providing significant financial support amidst rising living costs. The MDX Internship Scheme received overwhelmingly positive feedback from staff and students, highlighting its effectiveness in enhancing employability skills and providing financial relief. The scheme,

incorporated opportunities with the local business community in Barnet, further broadening its reach and impact.

C. Internship Communication and Selection Process

The MDX Internship Scheme utilised a structured recruitment and communication process that mirrored real-world hiring practices. This ensured transparency and fairness while equipping students with job application skills critical for employability.

The Internship roles were advertised through the internal Unitemps portal. Clear and engaging job descriptions, tailored with input from hiring managers and the Careers and Employability Service, outlined responsibilities, required skills, and expected outcomes. Additionally, career advisors hosted workshops and webinars to raise awareness and guide students through the application process.

Applicants underwent a multi-stage recruitment procedure, including tailored CV submission, cover letter evaluation, and virtual interviews. Employability advisers pre-screened applications to ensure alignment with role requirements, and hiring managers conducted final interviews. Feedback was provided to all applicants, emphasizing areas of improvement and strengths, making the process a developmental experience for students.

D. STEM Interns Reflections

Examples of STEM internships are listed Table IV and included a Year 2 undergraduate working on a *Campus Digital Twin* project for the Estates department, a PhD student contributing to the *Curriculum Co-Creation for Embedding UNSDGs & Climate Framework into Education* with the Pedagogic Research Group, and a postgraduate student conducting a *Sustainable Workplace* behaviour impact case study with the Barnet Council. Other roles included projects such as *Digital Twins for Cyber-Physical Systems* and a live research project like *DigIT—Digital Twins for Integrated Transportation Platform* at the London Digital Twin Research Centre, *Changing the Culture in STEM* with the Design Engineering and Mathematics Department, and Technical Laboratory Assistantships in both the Mechatronics and Robotics labs within the same department.

The reflections from the interns offered valuable insights into the professional growth, challenges, and learning outcomes they experienced during their internships. Below is an analysis of these narratives, categorised into key themes, namely: skill development and practical practice, communication and collaboration, personal growth and confidence building, sustainability and societal impact, challenges and lessons learned. Figure 2 illustrates the key themes and insights from the intern's reflections.

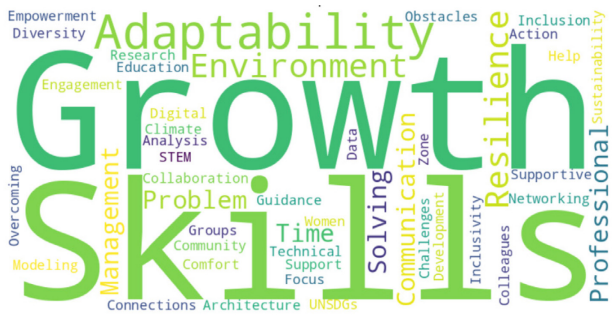

Fig 2. World cloud with key themes and insights in the interns' reflections

- **Skill development and practical practice:**

The interns frequently emphasised how the internships allowed them to translate theoretical knowledge into practical skills, often in dynamic and challenging contexts.

Intern 1 applied architectural principles by developing a digital twin model of a campus building, reflecting on their enhanced accuracy and technical proficiency:

"I initially measured the building's dimensions manually, which was challenging yet fun. As I progressed, I found section and elevation drawings that enabled me to enhance the model's accuracy and gain better understanding of the building structure."

In terms of competencies gained, this demonstrates technological agility and problem-solving and delivery. Similarly, Intern 3 gained insights into workplace behaviour and sustainability during their case study at Barnet Council:

"My case study centred on Barnet's main office, particularly the fourth floor and common spaces like the reception, café, circulation areas, and terrace."

This aligns with curiosity and learning and sustainability awareness as gained competencies.

Internships provided opportunities for students to develop critical professional skills, including time management, adaptability, and communication. For example, Intern 6 developed organisational and project management skills:

"This experience enabled me to enhance several transferrable skills, particularly time management, adaptability, and email communication."

This reflection aligns with leadership and influence and communication, empathy, and inclusion as gained competencies. Intern 7 emphasised time management:

"This experience taught me that no matter how well I plan, there's always a chance that unexpected setbacks can arise. To accommodate for this, I learned the importance of setting an internal target before the actual deadline."

This aligns with resilience and adaptability and problem-solving and delivery as gained competencies. Intern 8, who worked on the DigIT—Digital Twins for Integrated Transportation Platform, reflected on the steep learning curve of applying computer vision and machine learning techniques to real-world data sets from an Indian partner:

"This project was a challenging yet rewarding experience. Working with real data sets pushed me to not only apply my existing knowledge of machine learning but also acquire new skills in computer vision. It was exciting to see theoretical concepts put into practice and to learn so much in the process."

This reflection highlights the competencies of technological agility, problem-solving and delivery, and curiosity and learning.

- **Communication and collaboration:**

Interns reflected on the importance of effective communication and collaboration in achieving their project goals. For example, Intern 3 noted the value of engaging with various stakeholders to achieve the project outcomes, despite challenges:

"I engaged with Barnet office employees to learn about their daily habits, such as printing practices, food consumption, and waste disposal."

Intern 2 reflected on navigating diverse perspectives during the focus groups:

"My communication and interpersonal skills were tested, as I had to navigate differences in perspectives while ensuring that everyone felt heard and valued."

- **Personal growth and confidence building:**

Intern 5 described how the experience encouraged them to seek assistance beyond their immediate circle, leading to faster progress:

"At first, I only contacted individuals I was already familiar with, which slowed my progress. However, once I began reaching out for assistance to more people, my work accelerated considerably."

Intern 4 reflected on the rewarding nature of her internship in promoting inclusivity in STEM:

"Collaborating with inspiring women in STEM has been so rewarding. Seeing the challenges women in STEM face made me realise the importance of creating an inclusive environment."

- **Sustainability and societal impact:**

Sustainability emerged as a strong theme, with interns engaging in projects that addressed environmental and societal challenges.

Intern 3 internship coincided with Barnet Council's Climate Action Month, allowing them to explore practical applications of sustainability:

"Workshops such as 'Climate Risk in London and Across the Borough' broadened my understanding of the council's role in addressing climate change."

Intern's 2 project was centred on integrating sustainability goals into curricula, underscoring the role of education in promoting climate action:

"The project aimed to incorporate sustainability goals into curricula to equip students across all disciplines with the knowledge and skills needed to take climate action."

This reflection demonstrates the alignment with sustainability awareness and curiosity and learning as gained competencies.

- **Challenges and lessons learned:**

The interns acknowledged the obstacles they faced and the lessons they derived from overcoming these challenges.

Intern 4 faced limitations in data collection but adapted their approach by leveraging their initial observations:

"I faced challenges in obtaining detailed data... This limitation forced me to rely on my initial observations and interactions."

Intern 7 reflected on their time management strategies and their reluctance to seek help from unfamiliar individuals, recognising these areas for growth:

"Managing time in light of unforeseen issues is another area where I can enhance my proactive strategies for addressing setbacks."

Intern 8 reflected on the steep learning curve of his internship, highlighting how overcoming challenges contributed to his professional growth:

"Working with complex real-world data sets in an international research project was initially overwhelming. However, by persevering and seeking guidance when needed, I grew significantly, both technically and professionally."

The internships provided valuable opportunities for the interns to develop and refine competencies that are critical for success in academic, professional, and societal contexts. By mapping their experiences to competencies such as sustainability awareness, communication, technological agility, and resilience, it is evident that these internships played a pivotal role in equipping them with skills aligned with modern workforce demands. These reflections highlight the transformative potential of well-structured internships in fostering both personal and professional growth.

E. Employers Feedback

Figure 3 represents the world cloud generated from the employers' feedback. It emphasises key attributes such as diligence, collaboration, proactivity, and innovation, reflecting the positive feedback provided about the interns.

The employers' feedback highlights the exceptional performance and contributions of the interns in their respective roles. They were commended for their diligence, inquisitive nature, and ability to exceed expectations by laying the groundwork for their respective projects. Their initiative and collaboration with the broader team stood out

Fig 3. World cloud with key attributes from employer's feedback

as key strengths. Similarly, Intern 3 was praised for their proactive approach to improving workplace sustainability within the London Borough of Barnet's Sustainability Team. They effectively engaged staff, conducted research on sustainable practices, and shared valuable insights during team meetings. All interns demonstrated a strong work ethic, adaptability, and the ability to deliver impactful results, leaving a positive and lasting impression on their respective teams.

F. Mapping to MDX Graduate Competencies

The interns' experiences can be directly mapped to the MDX Graduate Competencies (Table II), highlighting the transformative impact of the internships on their skill development and readiness for the workforce. Each competency was cultivated through unique and challenging projects, allowing students to bridge the gap between theoretical knowledge and practical application.

Leadership and Influence was demonstrated as interns took ownership of their projects, managing responsibilities independently and influencing their work environments. For example, promoting inclusivity in STEM (Intern 4) and fostering effective time management under dynamic conditions (Intern 7) showcased their ability to lead and adapt within challenging contexts.

Entrepreneurship was evident in the innovative approaches interns used to address project-specific challenges. By applying theoretical principles to real-world problems, such as using digital twins to model infrastructure (Intern 1) or applying machine learning techniques to analyse real-world datasets in an international collaboration (Intern 8), they demonstrated creativity and a forward-thinking mindset.

Communication, Empathy, and Inclusion were critical for the interns' success, particularly in roles that required stakeholder engagement or collaboration within diverse teams. Whether working with external partners to understand workplace habits (Intern 3) or navigating focus groups to incorporate diverse perspectives (Intern 2), interns cultivated interpersonal skills essential for inclusive and effective communication.

Curiosity and Learning were foundational to the internships, as interns embraced steep learning curves and acquired new skills. Projects involving sustainability frameworks (Intern 2), workplace behaviour studies (Intern 3), and computer vision techniques (Intern 8) allowed interns to explore unfamiliar concepts and tools, fostering a mindset of continuous growth and adaptability.

Collaborative Innovation was reflected in the teamwork and shared problem-solving inherent in many of the projects. Interns worked across teams and disciplines, leveraging collective expertise to deliver impactful outcomes, such as in cross-border research initiatives (Intern 8) or local sustainability programs (Intern 3). Additionally, seeking assistance from broader networks enabled rapid progress and innovation (Intern 5).

Resilience and Adaptability were developed as interns navigated challenges such as data limitations, time constraints, and unforeseen project hurdles. Intern 4 adapted to data collection challenges by leveraging initial observations, while Intern 7 employed proactive strategies to overcome setbacks, demonstrating an ability to thrive in complex and uncertain environments.

Technological Agility was evident in the interns' application of advanced tools and techniques, from digital twin modelling for infrastructure projects (Intern 1) to machine learning and computer vision for transportation research (Intern 8). Their ability to harness these technologies to address real-world problems exemplified their proficiency in leveraging modern technological solutions.

Problem Solving and Delivery underpinned the interns' ability to complete projects with measurable outcomes. Whether designing sustainable workplace solutions (Intern 3), creating digital representations of physical systems (Intern 1), or contributing to large-scale research projects (Intern 8), the interns demonstrated a results-oriented approach aligned with professional expectations.

Through the MDX Internship Scheme, interns developed a comprehensive range of skills that align with the eight MDX Graduate Competencies.

V. RECOMMENDATIONS

The enhanced integrated STEM framework, as proposed in Fig. 1, provides a forward-thinking model that aligns seamlessly with integrating structured internships into STEM education. By embedding practical experiences within this competency-driven framework, universities can bridge the gap between academic learning and workforce demands, ensuring that graduates are equipped with both technical expertise and essential soft skills.

As seen in this study, internships offer students a platform to apply competencies outlined in the STEM framework, such as problem-solving, communication, collaboration, and innovation within real-world contexts. This practical exposure not only reinforces theoretical knowledge but also enhances transferable skills like adaptability, resilience, and self-regulation, which are critical for navigating the complexities of Industry 5.0. Furthermore, internships provide an ideal environment for fostering sustainability-focused thinking, a key component of the enhanced framework, by involving students in projects that address societal and environmental challenges.

Integrating internships into the STEM framework also supports the development of human-machine collaboration skills, preparing students to work effectively with advanced technologies such as AI and IoT. These experiences promote ethical reasoning and a human-centric approach to innovation, aligning with the framework's emphasis on societal well-being and inclusivity.

To maximise the alignment of internships with the framework, universities could:

- **Embed Internships into Curriculum Design**: Ensure that internship experiences are explicitly linked to STEM competencies, with clear learning outcomes that reflect the framework's goals.
- **Leverage AI and Digital Tools**: Utilise technologies for personalised feedback and formative assessments during internships, enhancing the learning experience.
- **Foster Industry Partnerships**: Collaborate with industry stakeholders to provide internship opportunities that address real-world problems while aligning with sustainability and technological advancement goals.
- **Promote Inclusivity**: Design internship programmes that prioritise equitable access for underrepresented

groups, ensuring that all students benefit from these transformative experiences.

Through the integration of internships within the enhanced STEM framework, universities can create a cohesive learning ecosystem that prepares STEM graduates to lead in a globalised, rapidly evolving technological landscape. This alignment not only enhances employability but also empowers students to contribute meaningfully to sustainable and ethical innovation.

VI. Conclusions and Future Research Directions

The integration of structured internships within the enhanced STEM framework provides a transformative approach to STEM education, bridging the gap between academic preparation and workforce demands. This paper demonstrated how internships enable students to translate theoretical knowledge into real-world applications, fostering critical competencies such as problem-solving, collaboration, sustainability awareness, and technological agility. By aligning internship experiences with the competencies required for Industry 5.0, universities can ensure that graduates are equipped to navigate a rapidly evolving, human-centric, and technologically advanced professional landscape.

Internships within this framework not only enhance employability by cultivating technical and interpersonal skills but also promote inclusivity and sustainability. Projects addressing societal and environmental challenges prepare students to contribute meaningfully to global goals such as the SDGs and Industry 5.0 principles. The feedback from interns and employers highlighted the success of this integrated model, reflecting the alignment of academic outcomes with industry expectations.

This study highlights the transformative potential of structured internships in fostering critical competencies and bridging the gap between academia and industry. Future research will explore the following directions:

- Conduct long-term assessments to evaluate the career trajectories of students who participated in the MDX Internship Scheme, focusing on their employability, professional growth, and contributions to industry innovation.
- Investigate the barriers faced by underrepresented groups, particularly women and students from low-income backgrounds, in accessing internships. Propose strategies to ensure equitable opportunities.
- Develop actionable recommendations for higher education institutions and policymakers to institutionalize competency-driven internships as a standard component of academic curricula.

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