Integrating the United Nations Sustainable Development Goals into Engineering Education: A Practical Framework for Developing Future Leaders in Sustainability

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***Abstract*— The climate emergency is one of the most critical societal challenges of our time. Higher education institutions (HEIs) are increasingly seen as key drivers of sustainable development, as they prepare future leaders to tackle critical global challenges. HEIs are further identified as key players in advancing sustainable development by incorporating the United Nations Sustainable Development Goals (UNSDGs) and sustainability into their teaching and learning processes. This paper presents a practical approach to embedding the UNSDGs into the curriculum of BSc Architectural Technology programme at Middlesex University London which is a pioneering exemplar for embedding UNSDGs at programme level at Middlesex that inspired many undergraduate and postgraduate programmes to follow. The paper introduces a developed and tested framework that offers a step-by-step guide to aligning entire programs and individual modules with the UNSDGs. A core outcome of this research is the development of a baseline for high level integration and a competency matrix that classifies sustainability understanding into three levels: awareness and appreciation, analysis and evaluation, and application and creation. These matrices, alongside the framework, serve as a practical tool for educators aiming to incorporate sustainability into courses in a systematic way. Furthermore, this research offers resources, examples, and a visual workflow that can be adapted by educators to ensure that graduates are equipped with the necessary knowledge, skills and mindset to contribute to sustainable development.**

Keywords— SDGs Alignment to Curricula, Education as Sustainability, Practical Framework, Graduate Sustainable Skills

I. INTRODUCTION

The climate challenge is recognised as the main challenge of our time. There is a significant increase in our global carbon emissions since 2000. According to UN Environment Global Status Report in 2017 [1], the building and construction sector accounting for 40% of global carbon emissions, addressing this environmental impact is essential for educators as well as industry professionals. Achieving net-zero carbon targets and caring for both people and the planet highlight the urgent need to integrate sustainability education into built environment and engineering courses. This research explores the critical role of engineers in addressing global societal challenges through sustainable solutions, focusing on the integration of sustainability into engineering education for preparing future leaders. This focus will equip future professionals with the skills to drive meaningful change in the industry and contribute to a more sustainable future. Integrating the UNSDGs into HE curricula is a transformative strategy that empowers students with the knowledge, skills, and values needed to create a sustainable future, addressing complex global socioeconomic and environmental [2].

Many HEIs have put sustainability at the centre of their institutional strategy. According to [3], sustainability is pertinent across a wide range of academic fields, extending beyond those traditionally focused on environmental topics. Furthermore, [4] suggests the SDGs offer a valuable framework for integrating sustainability into curricula across all disciplines, fostering a holistic approach to sustainable education. This perspective highlights the importance of embedding sustainability principles and practices across diverse academic disciplines beyond traditional environmental courses within HEIs. Integrating the SDGs and climate frameworks into higher education curricula can effectively foster graduates with a sustainability-focused mindset who can be impactful agents of positive change [5].

Although there is broad acknowledgment of the importance of incorporating sustainability and the UNSDGs into higher education programs, achieving this integration within existing curricula presents significant challenges. While the literature emphasizes the advantages of aligning academic programs with sustainability objectives, there is a noticeable gap in providing step-by-step guidance for effectively implementing such changes. This is further complicated by the diversity of educational systems worldwide, each governed by distinct regulations, standards, and institutional frameworks.

Acknowledging the importance of sharing experiences related to the integration of the Sustainable Development Goals (SDGs), this study aims to provide valuable insights from the alignment process. It offers a step-by-step guide, detailing the workflow and frameworks developed for the Architectural Technology BSc program at the Faculty of Science and Technology at Middlesex University London. These approaches have not only been successfully implemented within this program but have also been adopted by many other courses at the university and beyond.

After a review of the literature in the next section, Section III presents the revalidation process of the Architectural Technology program as a case study. Section IV then provides an analysis and discussion of the developed workflow and framework, drawing on the insights from stakeholders. Section V further explores the development of baseline and

competency matrices, along with strategies for their implementation. Finally, Section VI offers concluding remarks and outlines potential directions for future research.

II. Literature Review

The integration of UNSDGs and sustainability into engineering and architectural education is rapidly advancing. Some academic programs address this by dedicating specific courses or modules, while others take a more holistic, program-wide approach. [6] presented efforts aligning UNSDGs to BSc Architecture programme at TU Delft. They used EOP (Engineering for One Planet) framework to build sustainability into coursework, which involved updating learning objectives across disciplines to meet SDG criteria. The authors highlighted challenges in balancing strict curriculum redesign timelines with evolving sustainability frameworks. They advocate for iterative improvements, rather than waiting for a perfect approach. They further advocated for a cultural shift to make sustainability a core element of education, rather than treating it as an additional topic.

Climate change is identified as one of the most urgent challenges confronting humanity, with its severely damaging impacts affecting the livelihoods of communities worldwide, as highlighted by [7] and referencing [8]. They further emphasised global efforts, such as the European Green Deal and the UN Sustainable Development Goals (SDGs), as policy drivers for sustainability [8], [9], [10]. Engineering programs are increasingly expected to prepare students to address complex societal challenges, with frameworks like the UK's Accreditation of Higher Education Programmes (AHEP4) highlighting the importance of integrating sustainability, ethics, and social responsibility [11], [12], [13]. Integrating sustainability into engineering education as highlighted by [7] presents significant challenges, as it requires careful alignment with accreditation criteria while balancing time and resource constraints that limit content delivery. They recognised the need for continuous adaptation and innovation in engineering education to address evolving challenges and industry demands. This highlights the importance of flexible approaches and faculty support in curriculum development.

Recently significance of the impact of engineering and built environment on the environment is being highlighted in literature and an increasing number of advocates such as the Accreditation of Higher Education Programmes (AHEP, 4th edition), RIBA 2019 [14] and Chartered Institute of Architectural Technologists call for prioritising sustainability.

A systematic review of pedagogical approaches in teaching sustainability in planning and design education was conducted by [15]. Analysing 5639 empirical research documents published from 2011 to 2020, they identified 22 benefits, strengths and positive outcomes for teaching sustainability in planning and design education summarised in the table below. The four key benefits included (Fig. 1) enhancing problem-solving skills, gaining critical thinking abilities, developing design and planning skills and building collaborative skills.

III. Case Study: Revalidation of Architectural Technology Programme

In 2021, Middlesex University renewed its 10-year strategy through a cycle of consultation with staff. The process was carried out in a highly participatory manner, ensuring that the perspectives of all academic and professional staff were thoroughly considered. The university has placed a renewed emphasis on sustainability by signing the SDG Accord in 2021 and committing to achieving carbon neutrality by 2040. This commitment is supported by a global perspective that is becoming central to the university's strategic vision (Fig. 2) [16], along with a strong focus on integrating Education for Sustainable Development [17] throughout the curriculum as a foundational component of this approach published by AdvanceHE QAA [18] . The challenge was determining how to effectively translate this new strategy from a high-level directive into practical program delivery and everyday teaching.

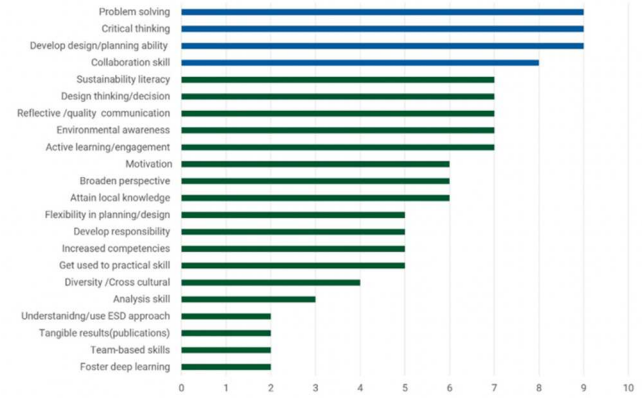


Fig. 1. Benefits of teaching sustainability in planning and design education [15]

Fig. 2. Middlesex University Strategy 2031link to SDGs

The BSc Architectural Technology was initially validated in February 2016 and revalidated in 2022 as it reached the end of its six-yearly lifecycle. The aim of this revalidation is to review and possibly renew the programme in a holistic and systematic way as opposed to making amendments to each module that can be done every year subject to the approval of university's academic board. The programme was further accredited provisionally by the professional body Chartered Institute of Architectural Technologists (CIAT) in Summer 2020 and was due to a full accreditation visit later in 2023. The overall aim of the programme is to ensure graduates leave with a thorough grounding in the key areas of architectural technology, and with the skills and competencies to adapt to the changing landscape of the industry. This paper presents the journey of fully embedding sustainability and UNSDGs to the programme, its modules, curricula and assessment during the revalidation process.

There is recognition that the built environment industry will go through significant change in response to the challenges identified in various published reports and impact on architectural technology professional diversity, adaptability, agility, and specialisation. The education

provision within architectural technology will need to reflect the changing context and currency and be more diverse and evolve within an industry that needs to go through major change together with a growth in specialisation, specialisms and an increasing need for specialists.

The ethos of the new programme was therefore centred around understanding the role and use of innovative technologies in creating a sustainable and inclusive built environment. Its core value is to educate graduates with enhanced knowledge of sustainable and inclusive built environment. The programme's key aims are to tackle current societal challenges such as sustainability/climate change, EDI/social responsibility, innovation and collaboration in the context of construction technology all of which in synch with the new Middlesex strategy.

The structure of the revised / revalidated programme shapes around innovations in four main areas (Fig. 3): Building technology and reforms of Building Regulations in particular in relation to Health & Safety, Information/digital technology, Sustainability technology and Inclusive technology.

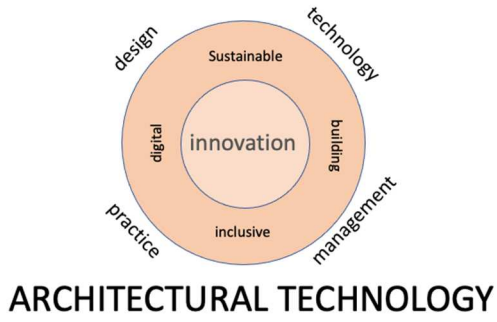


Fig. 3. Programme vision diagram

This summary highlights the core objectives and values of the program, offering a streamlined overview of how it aims to prepare graduates for societal challenges in architectural technology.

- **Comprehensive Knowledge and Skills**: Equip graduates with in-depth knowledge across four key aspects of architectural technology—Design, Technology, Management, and Practice—focusing on innovations in:
  - *Sustainable Technology*: Aligned with UN Sustainable Development Goals and Climate Framework.
  - *Digital Technology*: Following Digital Built Britain standards [19].
  - *Building Technology*: Adhering to UK Building Regulations with a focus on health, wellbeing, and safety.
  - *Inclusive Technology*: Emphasizing equity, diversity, inclusion, and ethical responsibilities.
- **Global Societal Impact**: Integrate the UN Sustainable Development Goals to address challenges such as climate action and sustainable communities, encouraging students to understand and reduce the construction industry's environmental footprint.
- **Professional and Ethical Development**: Prepare students for their role as Architectural Technologists within interdisciplinary teams, fostering ethical practices and enhancing career prospects.
- **Foresight and Adaptability**: Inspire students to anticipate changes in the field, with a focus on regenerative, sustainable, healthy, and inclusive environments to address pressing issues like the climate emergency.
- **Empowerment for Future Impact**: Instil a proactive, change-agent mindset, enabling graduates to navigate and influence the evolving role of architectural technologists.
- **Engaging Learning Environment**: Use active, practice-based learning to develop creativity, critical thinking, collaboration, and communication, fostering graduates' curiosity and sense of purpose.
- **Lifelong Learning Commitment**: Promote ongoing professional development through industry collaboration, highlighting the importance of staying current with research and consultancy in architectural technology.

In responding to the ever so important global challenge of climate crisis and sustainability and in line with University's 2031 Strategy the programme was aligned with the United Nations Sustainable Development Goals (UNSDG) in 2022. This was highly commanded by the review and validation panel and external assessors as best practice and an exemplar that followed by other programmes at Middlesex University.

IV. PROCESS OF SDG ALIGNMENT

Architectural Technology BSc was the first programme at MDX that embedded UNSDGs on Programme Level during its re-validation in April 2022. It was highly commended by the validation chair and external assessors for this innovative achievement.

The pedagogic approach was informed by QAA Architectural Technology subject benchmark [20], Chartered Institute of Architectural Technology (CIAT) our accreditation body requirements, AdvanceHE QAA Education for Sustainable Development [18], Climate Framework [21], UNESCO's Education for Sustainable Development A roadmap and RIBA Sustainable Outcome Guide [17] to name a few.

The climate emergency, sustainability, energy consumption, and carbon emissions are critical concerns in architecture and the built environment, with the construction industry contributing approximately 40% of global CO_2 emissions [19]. There are many recent movements and organisations advocating for sustainability and climate action. For example, Architects Declare, calls for architectural professionals to declare climate and biodiversity emergency and Architecture Education Declare campaigns for a curriculum change in relation to climate emergency. Architects Climate Action Network (ACAN) is another example of a professional and students network calling for carbon literacy to be embedded in education and for all UK households to declare a climate emergency. These guidelines as well as UK Government Net Zero Carbon target set for 2023/2050 were amongst the documents used to inform the process of evaluating the architectural technology programme and aligning it with educational and professional benchmarks and policy standards and targets.

While sustainable building design was already a component of the Architectural Technology programme at Middlesex University, and was taught in some of the modules, one specifically called Design Analysis and

Sustainability, the evaluation of the programme - for the 6 year-cycle revalidation - was conducted with the view of having a holistic approach to sustainability and aligning all modules to all UNSDGs to ensure the graduates develop an in depth knowledge, skillset and mindset to respond to the needs of the industry and be agents of change.

First a survey of literature was conducted to understand the trends and perspectives in this area. The integration of sustainability into higher education curricula has been widely discussed in the literature, with scholars emphasizing the need for transformative approaches that go beyond superficial inclusion to fundamentally reshape educational frameworks. For example, [22] argued that sustainability should reshape curricula, pedagogy, and institutional ethos, rather than simply adding to an already crowded curriculum. This perspective as demonstrated in Fig. 4 aligned with our goal of achieving the highest level of sustainability integration—transforming our education into "education as sustainability" rather than merely "education about sustainability" [23]. Their study examined the different levels of sustainability curriculum integration within higher education institutions (HEIs) and explored the factors affecting successful implementation. [24] categorised these levels from "denial" (no integration), through "bolt-on" (adding sustainability content without challenging existing frameworks), and "build-in" (critically embedding sustainability across curricula), to "redesign" (full integration, where sustainability is central to the institution's mission). Achieving the "redesign" level requires transformative paradigm shift that place sustainability principles, ethics and values at the core of the curriculum, involving broad institutional changes that engage leadership, faculty, and students.

The vision for the renew and revalidation of the architectural technology programme was to adopt this transformative approach. To implement this, the climate framework was adopted which is specifically designed for engineering education and aligns with the UNSDGs. Moreover, the vision was to ensure that environmental, social and economic aspects of sustainability are covered. Royal Institute of British Architects (RIBA) Sustainable Outcome Guide mapped the RIBA Plan of work (which are stages in an architectural project life cycle) to 9 SDGs. Climate Framework integrated with 12 of the SDGs. This showed the level of depth of covering SDGs needed to be different. A preliminary adaptation of this framework was initiated in 2022, aiming for full integration by 2025 with ongoing refinement through annual reviews.

Level		Type of ESD	Description	Pedagogical Approach
high/ very strong	redesign	education *as* sustainability	-holistic change and paradigm shift that places sustainability principles, ethics, and values at the core of the curriculum requiring the engagement of the whole person and institution -ESD is integrated into common core requirements and/or the vision of the HEI	emancipatory & transformative (third-order learning)
middle/ strong	'build-in'	education *for* sustainability	-significant changes to the curriculum by including a coherent coverage of content, values, and skills associated with sustainable development and a critical questioning of assumptions -sustainability is addressed in (interdisciplinary) programs/courses focusing on integrating sustainability issues -first linkages from ESD modules to other HEI areas such as operations/campus	
low/ weak	'bolt-on'	education *about* sustainability	-leaves current paradigm change unchallenged -sustainability concepts are added to specific disciplinary existing courses or programs (content based sustainability literacy) -minimal effort from the institution	instrumental & simplistic (first-order learning)
very weak	denial	no change	/	

Fig. 4. Levels of implementing sustainability in curricula [23].

Secondly, a programme - level evaluation was conducted in three phases based on the principle of looking at the past (reflections), present (landscape) and future (horizon) of the architectural technology profession, its context and the evolving role of an architectural technologist. The evaluation was informed by:

- Review of relative literature
- Reflective critical review sessions with the teaching team (SWOT Analysis)
- Meeting with the course External Examiner and their reports and feedback
- Workshop with current students & alumni about the programme
- students termly feedback
- Discussions with accreditation body CIAT
- Workshop discussions with industry practitioners, particularly employers of alumni
- Looking into similar courses offering nationally and internationally
- Guidelines and Benchmark Documents both academic and Professional

The framework's development is based on three key phases aimed at identifying the current and future needs of program graduates in relation to sustainability. The first phase, **"Look Around"**, involves reviewing national government targets, discipline-specific sustainability benchmarks, and professional accreditation requirements to ensure the curriculum aligns with both global and national priorities. This phase also includes consultations with employers and stakeholders, such as those who hire alumni, to pinpoint missing skills, knowledge, or competencies. The second phase, **"Look Back"**, involves engaging alumni and current students through focus groups and surveys to identify gaps in the program's sustainability education, particularly in areas where specific skills or knowledge are insufficiently addressed. The third phase, **"Look Ahead"**, focuses on ensuring that the program's alignment with the SDGs is measurable and evident in both teaching and assessment practices.

The workflow developed for the programme level integration of UNSDGs presented in Fig 5 outlining each phase and its outcomes.

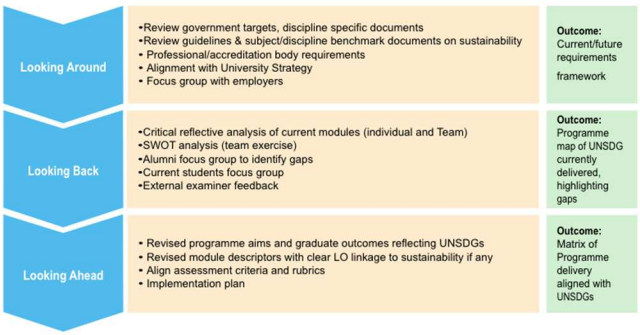


Fig. 5. Workflow for programme-level alignment to UNSDGs

A. *Look Around Phase*

The Look Around phase ensures that educational programs are comprehensive, relevant, and responsive to the evolving needs of society, the economy, and the environment.

This alignment process supports the development of a programme that is both relevant and forward-looking, equipping students with the knowledge and skills to address current and future societal and industry needs. The activities conducted in this phase are summarised below:

- **Review Government Targets and Discipline-Specific Documents**: Examining government policies, national targets, and sector-specific requirements [such as UK Government Net Zero targets and UK Government BIM strategy Digital Built Britian] helps institutions stay updated on priorities, such as sustainability, workforce development, and innovation. These targets often influence educational expectations and ensure that graduates are prepared to meet national and global needs.
- **Review Guidelines and Subject/Discipline Benchmark Documents on Sustainability**: Sustainability has become a core focus across many disciplines. By reviewing sustainability guidelines and benchmarks within specific subjects or disciplines, [in this case Architectural Technology Subject benchmark], institutions can embed relevant environmental and ethical principles in their curricula, aligning with broader societal goals like the UN Sustainable Development Goals.
- **Professional/Accreditation Body Requirements**: Many fields have professional bodies that set accreditation standards to ensure graduates have met certain competencies. By incorporating these requirements, [in this case CIAT benchmark standards], programmes ensure that students meet industry standards, enhancing their employability and eligibility for professional certification or chartership.
- **Alignment with University Strategy**: A university's strategic plan often outlines specific priorities, such as fostering innovation, promoting inclusivity, or advancing sustainability. Aligning curricula with these institutional goals ensures cohesion across programmes and supports the university's mission and values.
- **Focus Groups/ Workshops with Employers**: Engaging with employers helps HE institutions gather insights into the skills, knowledge, and competencies that are most valued in the job market. This direct feedback helps shape curricula to better meet employer expectations and ensures that graduates are equipped to succeed as future leaders in their industries.

B. Look Back Phase

The Look Back phase included critically analysing the current state of a curriculum or program to identify its strengths and areas for improvement. This involved reflection and input from multiple stakeholders—faculty, students, alumni, and external examiners—to create a comprehensive understanding of what was working and what could be enhanced. The goal of this phase was to highlight any gaps in the provision. The review was conducted through engaging in evaluation of the current programme which was done systematically through:

- **Critical Reflective Analysis of Current Modules (Individual and Team)**: Faculty members individually and collaboratively evaluate the content, structure, and delivery of their modules. This reflection helps identify any misalignments with desired learning outcomes, areas that may need updating, and teaching methods that could be improved. Individual analysis allows faculty to deeply consider their own modules, while team analysis encourages sharing insights and best practices across modules, fostering a cohesive curriculum for the programme.
- **SWOT Analysis (Team Exercise)**: A team-based SWOT (Strengths, Weaknesses, Opportunities, Challenges) analysis provides a structured approach for assessing the curriculum. This exercise allows the team to collaboratively discuss what the program excels at (strengths), areas needing improvement (weaknesses), potential areas for growth or innovation (opportunities), and challenges that may impact the program (challenges). SWOT analysis fosters a comprehensive understanding of the curriculum's internal and external contexts and can help prioritize areas for action.
- **Alumni Focus Group to Identify Gaps**: Alumni can provide valuable feedback on the curriculum's effectiveness in preparing them for their careers. Through focus groups, alumni can highlight gaps they encountered in their education—skills, knowledge, or experiences they needed but didn't receive. Alumni insights are especially valuable as they offer a retrospective view, with the benefit of real-world experience, to assess how well the program aligns with industry demands.
- **Current Students Focus Group**: Focus groups with current students allow for real-time feedback on their learning experiences. Students can share their perspectives on what is working well, what they find challenging, and where they feel unprepared or unsupported. This feedback provides insight into student satisfaction, engagement, and immediate areas for improvement, ensuring that the curriculum is responsive to current learners' needs.
- **External Examiner Feedback**: External examiners are typically experienced academics or professionals from other institutions who provide an objective assessment of the program's quality and standards. Their feedback includes observations on curriculum relevance, rigor, and alignment with industry and academic standards. External examiners can offer unique insights, helping ensure the program maintains academic integrity and meets the expectations of the wider educational and professional community.

Together, these components of the "Looking Back" phase offer a comprehensive review of the current curriculum, leveraging both internal and external perspectives to identify strengths, gaps, and areas for development. This analysis forms the foundation for informed improvements, ensuring the curriculum is relevant, effective, and aligned with stakeholder expectations.

This SWOT analysis provided insight into our program's current state and highlighted key areas for strategic development, including opportunities for alignment with sustainability, technology, and industry standards, as well as areas needing improvement to support student success and industry alignment. The discussions and feedback of the external examiner of the programme also incorporated into the

analysis. Fig. 6 shows an extract of the SWOT analysis which included external examiner's feedback and discussions.

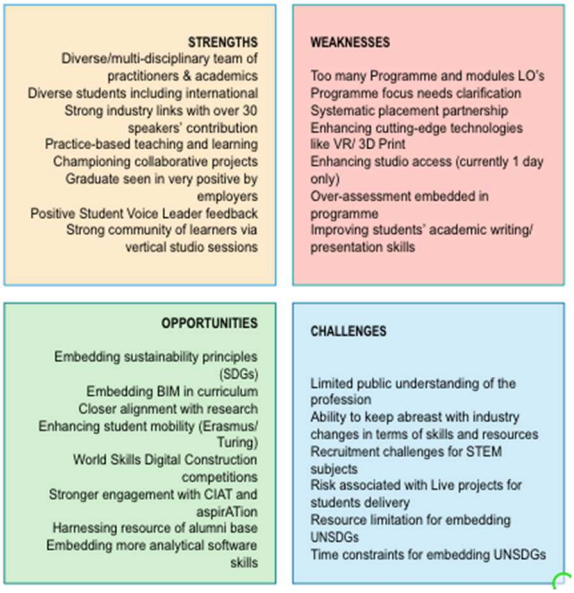


Fig. 6. Programme team SWOT analysis

The workshop conducted for current student and alumni identified areas for improvement or missing knowledge, skills, and competencies. Overall, the feedback was very positive and emphasized a desire for even more practical, hands-on experiences, earlier technical training in specific software, and continued access to real-world projects and fieldwork. Summary of alumni and students workshop insights is in Table I.

TABLE I. SUMMARY INSIGHTS FROM STUDENTS AND ALUMNI

Questions	Summary of responses
What did you like the most about the course?	Students appreciated modules on sustainability and BIM, real-life projects, practical experiences like working on the MDX Pavilion and field trips (e.g., to the CAT), as well as opportunities to apply skills in realistic settings. They valued hands-on learning and interaction with professional tools.
What did you like the least about the course?	Common criticisms included limited opportunities to test knowledge practically, a lack of interaction outside structured teaching, and an absence of a "studio" environment. Some felt there were unnecessary breaks between lessons, and certain modules, like history, were seen as less relevant. Students desired more practical exercises, competitions, and challenges to apply skills.
Did you feel any modules were better suited for another year?	Some students suggested moving certain professional context modules to later years for greater relevance. Others proposed introducing Revit and BIM earlier to enhance students' technical skills sooner. However, many felt that the modules were well placed within their respective years.
Skills/knowledge needed but not covered enough in the course	Students noted gaps in advanced skills with Revit, such as creating "families" in the software, as well as a need for more detailing and practical skills with BIM tools. Some students wanted more focus on hands-on craftsmanship and rendering skills, which they found essential for their roles but felt were not covered in depth.
Skills/knowledge that particularly helped with employment	Revit and BIM knowledge, familiarity with building regulations, and experience with AutoCAD were highlighted as valuable for employment. Projects like the MDX Pavilion and field trips provided practical experience and were frequently cited as assets in their professional roles.
Memorable/useful experiences during the course	Revit and BIM knowledge, familiarity with building regulations, and experience with AutoCAD were highlighted as valuable for employment. Projects like the MDX Pavilion and field trips provided practical experience and were frequently cited as assets in their professional roles.
Other suggestions/comments/feedback	Students suggested incorporating more site visits, field trips, and practical, hands-on exercises. Some recommended a greater focus on practical skills rather than presentation, emphasizing software training and hands-on craftsmanship. They appreciated the diversity of learning opportunities and felt that stronger practical applications would further enhance the curriculum.

Table II captures the employers' perspectives on the skills, involvement, and observations related to Architectural Technology graduates, particularly those from Middlesex University. While some of the students feedback was module related, overall sustainability was at the top of their positive feedback. The same was for the employers that expressed their expectations from graduates to know principles of sustainability and energy consumption through technical knowledge such as materials U-Value, thermal bridging, Passivhaus standards and related software tools.

TABLE II. SUMMARY INSIGHTS FROM EMPLOYERS

Technical Skills Expected	Graduates should have a solid understanding of Building Regulations, principles like U-values, thermal bridging, SAP, and Passivhaus. This knowledge will support their role in design development. Good detailing skills, problem-solving for technical issues, and familiarity with construction materials and methods are essential.
Digital Skills Expected	Proficiency in BIM and PAS/ISO standards is crucial, as well as familiarity with mainstream BIM software (e.g., Autodesk Revit, ArchiCAD) and visual scripting (e.g., Dynamo, Grasshopper). Knowledge of specification tools (e.g., NBS Chorus) and visualization tools (e.g., Enscape, Twinmotion) are also valued to help teams and stakeholders visualize and engage with designs.
Skill Differences Compared to Architecture Graduates	Architectural Technology (AT) graduates are expected to have a more technical and practical approach, especially in supporting architects with project development. They should contribute to delivering architectural ideas side-by-side with architects, not merely drafting or modeling. This role requires a deeper understanding of technical aspects that architects may not prioritize.
Impressive Skills Observed in Middlesex Graduates	Employers note strong software skills among Middlesex AT graduates, especially in BIM. There is an opportunity for employers to better leverage these graduates' broader knowledge gained during their course, potentially through deeper engagement with various course elements.
Areas for Improvement in AT Graduates	Employers mention gaps in understanding wider design/regulation knowledge (e.g., Building Regulations like Part M or Part B). While this is being addressed, there's a need for AT graduates to have a more balanced view of technical and regulatory requirements.
Desired Involvement with the Course	Employers are interested in supporting the program through guest lectures, webinars, workshops, project briefs, crit sessions, and summer placements. Some noted the need to assess commitment and time before increasing involvement.
Additional Comments and Feedback	Digitizing the industry could improve diversity by drawing from a wider talent pool. Lectures and webinars have already attracted a diverse audience, which employers see as a positive trend. They also express willingness to support the AT graduates within their practice.

Thematic analysis of the feedback (alumni/students, employers and team's swot analysis) presented in Table III highlights the strengths in practical, real-life applications and industry connections, while suggesting improvement in legal/professional knowledge, software proficiency, and real-world assessment opportunities. Leveraging opportunities to integrate sustainability, advanced technologies, and industry partnerships can help mitigate the external challenges of limited awareness and rapid industry evolution.

Overlaying the results of the students, alumni and employers feedback analysis with reflective analysis of the team generated a set of combined insights including:

- **Strengths**: Across students, employers, and SWOT, practical skills, real-world projects, and industry links are considered key assets. The diversity of students and faculty, along with strong community learning environments, enhances the program.
- **Weaknesses**: Both students and employers note gaps in practical application and legal/technical detailing. The SWOT analysis further highlighted issues with over-assessment, too many learning outcomes, and a need for program focus refinement.
- **Opportunities**: Students, employers, and the SWOT analysis identify opportunities to integrate sustainability principles (aligned with the SDGs), BIM, advanced software skills, and structured placements to enhance industry alignment.
- **Challenges**: While not directly mentioned by students or employers, the SWOT analysis points to challenges including limited public understanding of the profession, risks with live projects, and the challenge of staying updated with industry changes.

TABLE III. THEMATIC ANALYSIS

Criteria	Student Feedback Summary	Employer Feedback Summary	SWOT Analysis Insights
Overall Experience	Positive about hands-on projects, with requests for more practical application opportunities.	Graduates are well-regarded for practical skills but need improvement in specific areas.	Strong community of learners with positive feedback on vertical studio sessions and collaborative projects.
Strengths	Enjoyment of sustainability and BIM modules, real-life projects, and practical work.	Graduates have strong software skills (e.g., BIM) and collaboration abilities.	Diverse, multidisciplinary team and strong industry connections with guest speakers; positive feedback on graduate skills.
Weaknesses	Lacks real-world testing knowledge; need for better academic writing support.	Emphasis needed on legal, procurement, and management skills.	Excessive learning outcomes; need for better alignment and clarity in program focus; over-assessment in certain modules.
Skills Emphasis	Requests for advanced software skills, particularly Revit and rendering techniques.	Desire for stronger technical detailing and practical Revit application.	Opportunity to include more advanced digital and analytical software skills in the curriculum.
Practical Application	Desire for more site visits, practical modeling, and real-world technology experience.	Value in real-life projects, but further professional skills preparation needed.	Potential to enhance studio access, adopt cutting-edge technology (e.g., VR), and develop structured placement opportunities.
Modules Suitability	Certain modules could be restructured across academic years to improve skill progression.	Professional context modules should be covered later to align with career demands.	Opportunity to embed sustainability (SDGs) and BIM into the curriculum for better alignment with industry trends.
Memorable Experiences	Field trips, collaborative projects, and hands-on assignments are highly valued.	Industry speakers and projects that foster collaboration are seen as valuable.	Industry collaboration (e.g., World Skills Digital Construction competitions) and alumni engagement are areas for growth.
Recommendations for Improvement	Increase practical assessments, site visits, and improve	Align curriculum with industry	Need for systematic industry placement partnerships and resources to keep pace with

C. *Look Ahead Phase*

The "Look Ahead" phase involved forward-thinking programme updates to ensure that programme goals and outcomes meet evolving educational and professional standards, with a focus on sustainability and alignment of the learning outcomes, teaching, curriculum and assessment to the SDGs [25]. Here's a breakdown of each stage in this phase:

- **Revised Programme Aims and Graduate Outcomes Reflecting UNSDGs**: Program goals and focus are redefined to incorporate the UNSDGs, ensuring that graduates are equipped to address global challenges like climate action, social equity, and sustainable resource use. By embedding these goals, the program positions its graduates as responsible professionals ready to contribute positively to society and the environment. The programme learning outcomes were streamlined from 26 to 15 to ensure greater clarity and focus.
- **Revised Module Descriptors with Clear Learning Outcome Linkage to Sustainability**: Each module descriptor is updated to clearly outline how it contributes to sustainability, with explicit learning outcomes (LOs) tied to these goals where relevant. This ensures that students understand the role of sustainability in their studies and recognize the specific skills and knowledge they gain that relate to sustainable practices.
- **Align Assessment Criteria and Rubrics**: Assessment methods and rubrics are adjusted to evaluate students' understanding and application of sustainability principles in line with the revised LOs. This alignment ensures that assessments measure the intended outcomes and provide students with clear expectations on how to integrate sustainability into their work.
- **Implementation Plan**: A structured alignment plan outlines the steps and timelines for rolling out these changes. It includes training and support for faculty, updates to teaching resources, and milestones for evaluating progress. This plan ensures that all modifications are effectively integrated into the curriculum and that faculty and students are supported throughout the transition (Fig. 7).

The "Look Ahead" phase sets a clear path forward, ensuring that the program remains relevant, impactful, and aligned with global sustainability goals, preparing graduates for careers that meet current and future industry standards.

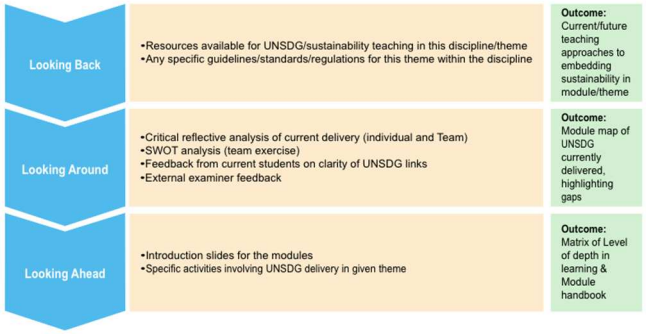


Fig. 7. Workflow for module-level alignment to UNSDGs

This opportunity has been taken to update the program design, making changes that align with recent shifts in the professional landscape. The content has also been rebuilt to incorporate digital innovations, offering students a systematic, career-oriented focus on sustainability and BIM. The program's unique learning, teaching, and assessment strategy is grounded in reflective, practice-based learning and the principles of professional and ethical collaborative practice. This approach is realized through an innovative pedagogy that incorporates industry collaboration and real-life projects, making assessment an integral part of the learning process. In that there is no examination, and all assessments are through coursework. The project brief for each module is issued in the first two weeks and that students work throughout the term on the project until the submission with ongoing feedback. While each assessment brief has a primary focus on one or more SDGs, it also connects to some others. Students are actively engaged in both the acquisition and application of knowledge, fostering deeper, practice-oriented learning.

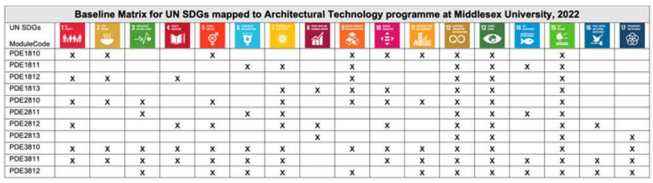
V. RESULTS AND DISCUSSION

The importance of Education for Sustainable Development (ESD) as a crucial driver of sustainable development has been increasingly recognized on a global scale [25]. A disconnect between climate change research and education has been identified, with insufficient progress in adapting curricula and pedagogy to address climate action, particularly within built environment courses. This delay has led to a gap in students' acquisition of essential knowledge and skills in key areas of mitigation and adaptation [26]. As such, systematic aligmnet of SDGs on programme and module level, including curriculum and assessment, requires an action-based iterative approach. Furthermore, target 4.7 of the SDGs [25], aims to ensure that by 2030 all learners gain the knowledge and skills necessary to support sustainable

development. The following section showcases the iterative development of the competency matrix, which facilitated the alignment of the architectural technology programme with the SDGs, supported by worked examples.

A. Development of Baseline Matrix

Following a thorough analysis, the new program was redesigned with its modules aligned to subject benchmarks, guidance documents, and the University's new 2031 strategy, which emphasizes sustainability as a core pillar. A detailed review of the existing program revealed that while some modules were sustainability-focused, others lacked a systematic approach to embedding sustainability principles. To address this, the programme modules were restructured and eleven new modules created, incorporating updated knowledge, skills, and competencies. Additionally, a baseline matrix was developed (Fig. 8) to map all 17 SDGs to each new module, represented by their respective codes in the matrix below. Module codes listed in the first column left against all 17 SDGs listed in the first row. For each module the relevant aligned SDGs were ticked. The approach is applicable for both undergraduate and post-graduate programmes.



Baseline Matrix for UN SDGs mapped to Architectural Technology programme at Middlesex University, 2022

UN SDGs / ModuleCode																	
PDE1810	x	x			x				x	x	x	x	x		x		
PDE1811						x	x		x			x	x	x	x		
PDE1812	x	x		x					x			x	x		x		
PDE1813							x	x	x	x		x	x		x		
PDE2810	x	x	x		x		x		x	x	x	x	x		x		
PDE2811			x			x	x					x	x	x	x		
PDE2812	x			x	x		x	x		x		x	x		x	x	
PDE2813								x				x	x		x		x
PDE3810	x	x	x	x	x	x	x		x	x	x	x	x		x		x
PDE3811	x	x	x	x	x	x	x			x	x	x	x	x	x	x	x
PDE3812			x		x	x	x		x		x	x	x	x	x	x	x

Fig. 8. SDG Alignment Baseline Matrix

The next step involved examining each Sustainable Development Goal (SDG) in relation to each newly created module to identify alignments. This process aimed to ensure that students, through the entire programme, acquire knowledge, competencies, and skills across all three pillars of sustainability: environmental (biosphere), economic, and social. To systematically relate the SDGs to each module, the 'Wedding Cake' model [27] was applied. This model's categorization (Fig. 9) helped ensure that all three sustainability categories are addressed in each year of the undergraduate program, promoting a well-rounded understanding of sustainability and the interconnections among the SDGs.

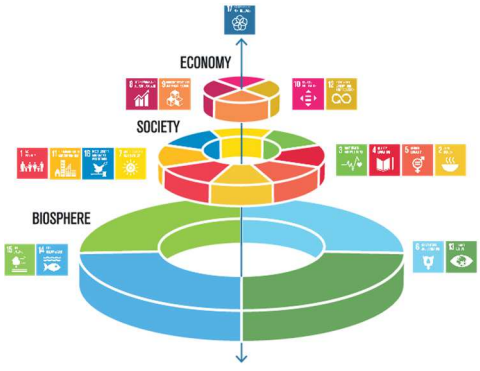


Fig. 9. SDGs Wedding Cake Model [27]

B. Development of Competency Matrix

In the Architectural Technology program, integrating nine SDGs identified by the RIBA Sustainable Outcome Guide (SDGs: 3, 6, 7, 8, 9, 11, 12, 13, 15) proved relatively straightforward. However, other SDGs, such as SDG1: No Poverty, were initially seemed less directly relevant to the built environment context. However after discussions, it was concluded that engineering knowledge and skills can be used to eradicate poverty through designing affordable housing for example. This connected SDG1 to property development and regeneration projects, emphasizing their impact on the local economy. (UNESCO 2017) framework was used to explore the content, suggested topics and learning approaches and methods for each SDG and how they are linked to the discipline of architectural technology. Ultimately, all 17 SDGs were mapped to the program in 2022, with the understanding that the focus and depth of each SDG would vary based on their relevance to the discipline.

After aligning the new program's module descriptions and learning outcomes with the SDGs, curriculum content, teaching methods and assessment materials were developed during the 2022/23 and 2023/24 academic years. An ongoing evaluation found that each SDG was addressed at varying levels of depth across modules. Three levels of depth in relation to learning objectives are outlined, encompassing cognitive, socio-emotional, and behavioural dimensions. These levels highlight the diverse aspects of learning that contribute to a comprehensive educational framework [25].

- **Cognitive learning objectives** in relation to each SDG is entry level and focused on understanding the concepts and knowledge development.
- **Socio-emotional learning objectives** are intermediate level focusing on learners ability to evaluate and communicate on the issues and connections between them and collaborate with others to raise awareness in relation to the SDGs in question.
- **Behavioural learning objectives** refer to the ability of the learner to plan, take action and implement solutions to tackle the problem. This level translates into change in behaviour and practice influencing decision- making.

Ensuring measurable alignment with SDGs, a competency matrix was developed to represent the different levels at which SDGs were integrated and assessed within each module.

Corresponding to the UNESCO's learning objectives, three levels of competency were defined as:

1) Awareness and Appreciation – an introductory understanding of the SDG's fundamental principles.

2) Analysis and Evaluation – an intermediate level involving analysis and discussion of the SDG.

3) Application and Creation – a systematic, practical understanding of the SDG and its interdependencies within the discipline.

Both the baseline and competency matrices apply to undergraduate and postgraduate programs and can be adapted for diverse institutional contexts and disciplines beyond architecture and engineering.

The competency matrix was developed as part of the second iteration and evaluation of the program in 2024, following the implementation of a new learning framework introduced by the university. Student feedback on the systematic integration of SDGs in teaching and assessment over both academic years has been very positive, supporting the development of future leaders in the discipline. Additionally, an ongoing research project, funded by the Enhancing Education Fund, focuses on student engagement in curriculum co-creation for sustainability, which will further

inform and enhance the program. Fig. 10 presents the relationship between the competency levels developed in this study and the UNESCO learning objectives for achieving the SDGs. The model serves as an implementation plan supporting writing specific learning outcome on both programme and module level.

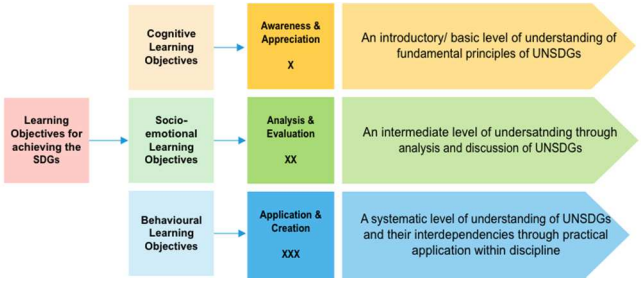


Fig. 10. Model alignment of UNESCO learning objectives with competency level

The Sustainable Development Goals are interconnected and often overlap in their scope and objectives. This interconnectedness allows them to be integrated into various aspects of learning rather than being confined to a single module. By embedding SDGs across multiple modules, educators can address their multifaceted nature, highlight their interdependencies, and encourage students to develop a holistic understanding of sustainability. This approach not only enriches the learning experience but also ensures that students gain diverse perspectives on how different goals can collectively contribute to sustainable development. Fig. 11 presents the competency matrix aligning SDGs with all eleven modules of the architectural technology BSc programme.

Module codes are populated in the first column (from left) and for each module (presented by their code) the SDGs aligned are ticked based on three levels of competency. Number of X corresponds to level of competency. Colors are for additional visual aid. The matrix can be used both for undergraduate and post-graduate programmes.

The competency matrix supports other educators of any discipline in their journey of embedding sustainability into education to develop future leaders in the field [28]. Aspects of the workflow presented in Engineering Professors Council Sustainability Toolkit [29] as part of an open-access platform designed to help engineering educators integrate sustainability-related content into teaching and supported by Royal Academy of Engineering and Siemens.

Furthermore, CIAT, the accreditation body for the architectural technology course, like other professional bodies, has established a set of mandatory threshold standards that must be met. While sustainability and Education for Sustainable Development (ESD) serve as overarching principles of the profession, linking each module to both the SDGs and CIAT's mandatory thresholds—alongside subject quality assurance benchmarks and graduate competencies—adds additional layers of interdependency. This complexity as identified by [7] and [30], necessitates a systematic approach to ensure cohesive alignment across all components.

Fig. 12 ultimately illustrates the programme modules presented with their codes in the middle and their alignment with the SDGs as well as CIAT's mandatory threshold standards. To enhance clarity, modules across the three undergraduate years are color-coded consistently. The lines linking modules to the SDGs vary in thickness, reflecting the corresponding competency levels. This visualization aims to effectively capture and communicate the intricate and interconnected nature of the system.

VI. CONCLUSIONS

The insights from this paper are intended to serve as a practical guide for built environment and engineering programs at other universities aiming to integrate UNSDGs into their programmes. However the framework is scalable in that it can be adapted to the requirements of any discipline, simply by considering the quality standard frameworks and discipline specific outcomes.

The impact of the UNSDG integration framework on student learning and outcome is reflected in various metrics such as SDG impact ranking and annual reports required from academic institutions. Considering the evolving nature and constant changes in technology and innovation, academic programmes need to be constantly renewed and reviewed to be relevant. This study offers a practical framework for educators to integrate Sustainable Development Goals (SDGs) into higher education curricula, relevant to any discipline. This step-by-step guidance supports academics of any subject area to align programmes with UNSDGs.

Three stages of the framework include 'Identify Needs', which focuses on reviewing industry standards, sustainability guidelines, and consulting employers to identify the essential skills for graduates; 'Assess Current Alignment', involving an evaluation of existing programs through reflective analysis, alumni and student feedback, and mapping gaps in SDG coverage; and 'Implement Changes', which entails revising

Competency Matrix for UN SDGs mapped to Architectural Technology programme at Middlesex University, 2024

UN SDGs / Module	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PDE1315	X	X		X					X			X	X		X		
PDE1316							X	X	X	X		X	X		X		
PDE1811						X	X		X			X	X	X	X		
PDE1817	X	X			X				X	X	X	X	X		X		
PDE2813								X				XX	XX		XX		X
PDE2811			X			XX	XX					XX	XX	XX	XX		
PDE2317	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
PDE2817	XX	XX	XX		XX		XX		XX	XX	XX	XX	XX		XX		
PDE3806			X		X	X	X		X		X	X	X	X	X	X	X
PDE3817	XX	XX	XXX	XX	XXX	XXX	XXX		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XX	XX
PDE3823	XX	XX	XXX	XX	XXX	XXX	XXX		XX	XXX	XXX	XXX	XXX		XXX		XX

XXX	**Application & Creation**	A systemic level of understanding of UNSDGs and their interdependencies through practical application within discipline
XX	**Analysis & Evaluation**	An intermediate level of understanding through analysis and discussion of the relevant SDG
X	**Awareness & Appreciation**	An introductory / basic level of understanding of fundamental principles of the relevant SDG

Fig.11. SDG Alignment Competency Matrix

program goals, learning outcomes, and assessments to ensure direct alignment with the SDGs. This framework equips educators to systematically embed sustainability into their programs, fostering critical skills needed to address global challenges. The baseline and competency matrices help educators systematically align modules with SDGs, providing a detailed focus and understanding that underpins both assessment and curriculum design.

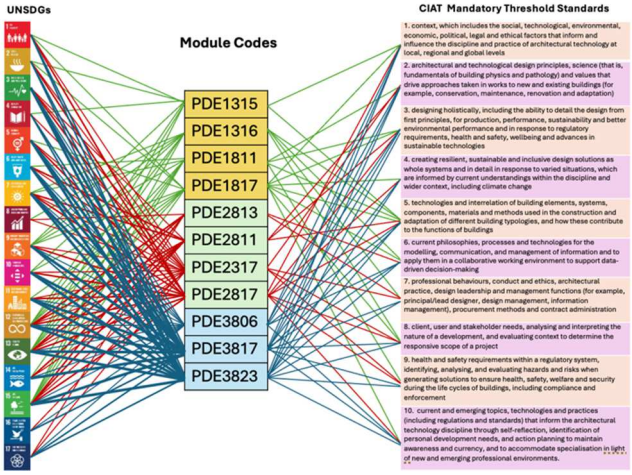


Fig. 12. SDG and CIAT mandatory threshold alignment

Undergraduate and post-graduate education in built environment and engineering must integrate climate adaptation and sustainability through a collaborative approach involving universities, professional bodies, industry professionals, policy makers and community organisations. Aligning curricula with the SDGs requires these stakeholders to share knowledge, identify skills gaps and ensure training and education reflects real-world challenges. Collaborative efforts ensure equipping students with interdisciplinary skills, fostering future leaders capable of addressing climate change.

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