Embedding Interdisciplinary Research-Based Education for Sustainable Development in Higher Education through Vertically Integrated Projects

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Abstract: Historically, Universities have been regarded by employers as generators of 'neatly boxed' lawyers, chemists, engineers, etc. who could be (and perhaps some saw it better that they were) completely divorced from, or agnostic about, the challenges of the world around them, while operating within their own disciplinary silos. However, there is now a growing recognition across society, industry and business that such is the complexity and uncertainty associated with the global challenges of today, that these problems cannot themselves be viewed, defined or indeed solved through such a disassociated and disjointed disciplinary approach. These are not just 'engineering' problems, or 'legal' problems, or singularly social, environmental or economic problems; they are all of these and more - and at all the same time. Consequently, focusing teaching on ways of thinking, being and practicing, and so how students think, feel and act in relation to the rapidly changing world around them, should be done in a way that actively stretches students beyond the comfort of their disciplinary subject boundaries and skill sets. This makes for not only more socially aware, empathetic, emotionally intelligent, connected, cooperative and ethically responsible graduates, but ensures they are equipped with the types of disciplinary, interdisciplinary and trans-disciplinary competencies that will be required to meet the challenges required "to safeguard our social, economic and environmental wellbeing – now and for future generations" (UNESCO, 2019). This paper seeks to explain and justify, at a pedagogical level, the suitability of Strathclyde's Vertically Integrated Projects for Sustainable Development (VIP4SD) programme as an experiential learning vehicle through which engineering undergraduates (and others) can engage in meaningful, purposeful and transformational interdisciplinary research on global sustainability challenges.

Keywords; Vertically Integrated Projects, Interdisciplinary Research-Based Education for Sustainable Development, Active Learning, Experiential Learning.

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1. INTRODUCTION

A key question posed by Kreber (2009a) is - "to what extent does the undergraduate experience prepare students for the complexities and uncertainties that characterize their later professional, civic and personal lives?" This question gets to the heart of the issue around whether an *authentic* (engineering) education is genuinely one that can be taught almost predominantly and rigidly within its own disciplinary silo, focused on tightly regulated, subject-specific curriculum content, and through a largely transmissive, instructional approach. Such an approach may be considered to lack authenticity in that it is largely devoid of opportunities to meaningfully connect the discipline and its students with students from other disciplines and to genuine real-world challenges akin to a workplace experience. Instead, the responsibility for this is, for the most part,

deferred to 'on-the-job' training after University. This discipline and subject-centric approach is the traditional blueprint for undergraduate education – with perhaps student placements (e.g. in vocational degrees such as medicine or nursing) and internships opportunities offering respite, as well as some less orthodox interventions from more independent-minded, and often smaller, private HE disruptors (LIS, 2022) (Olin, 2022).

Often the types of skills that are the focus for development throughout a 'typical' undergraduate degree are also very discipline-oriented. In engineering programmes these skills tend to be extensively technical. There are of course opportunities for learning what are referred to as 'soft skills', but what is missing here are the types of skills and competencies that actually amount to a new 'way of thinking' more in tune with the realities of the world around us and that lead to a more transformative learning experience for students. Such skills and competencies may be considered transdisciplinary, i.e. those that go beyond the discipline and which can be used more generally in the student's professional and personal life. This has been a long-standing topic of debate and consternation amongst many educationalists. Kreber (2009b) points out how the Dorothy Sayer's essay "The Lost Tools of Learning", published in 1948, emphasised that "the great defect in our education today … [is that] although we often succeed in teaching pupils a 'subject', we fail lamentably on the whole in teaching them how to think" (Sayers, 1948). Arguably not enough progress has been made on teaching students 'how to think' and "why what they think matters in the context of the world around them and how they interact with it" (Palmer, 1998).

Perhaps it is the perceived risk of inadvertently diluting or compromising the specialist disciplinary, technical knowledge and skills of an engineering degree (or any other), to 'make way for' competency development, that contributes to what Sayer and her proponents might consider the 'great defect' in our education. Perhaps, more generally, as posited by Northedge and MacArthur (2009), "uncertainties lurk as to whether the essence of higher education will somehow be lost and what the role of the teacher will be as new configurations of higher education emerge". However, such a perspective suggests attainment of subject knowledge and competency development are separate endeavours, with competency development as an adjunct provision. Conversely, interweaving the development of these transdisciplinary competencies with knowledge attainment and production, through the student's interaction with other disciplines and stakeholders in a real-world context, offers opportunities for education enhancement that increase the student's learning capacity. Here, they can engage in a deeper understanding of the discipline, domain and world around them. Therefore, greater appreciation and acknowledgement of the need for a more balanced coexistence and indeed interplay between 'what students learn', 'how they think' and 'why it matters' is required to embrace pedagogies that can work to embed transdisciplinary competency development in HE teaching practice. The VIP4SD programme is an exemplar of 'how to' embed experiential, competency-based, inter-disciplinary, Research-Based Education for Sustainable Development (RBESD) in HE curricula.

2. UNDERGRADUATE RESEARCH-BASED EDUCATION

2.1 What is meant by Undergraduate Research?

The US Council on Undergraduate Research define 'undergraduate research' as "an *inquiry* or investigation conducted by an undergraduate student that makes an original, intellectual, or creative contribution to the discipline" (CUR, 2022). For some, like the University of North Florida, it is less about making a novel contribution to a field, and more about the pedagogical

approach it offers in inculcating students with an ability and capacity to engage in a process of *inquiry* that can lead to the discovery and production of knowledge. However, there is consensus that *inquiry* sits at the centre of the student's overall active learning research experience.

2.2 Inquiry-Based Learning, Problem-Based Learning and Design Thinking

Bianchi and Bell (2008) indicate how Inquiry Based Learning (IBL) comes in different forms. In most forms the teacher provides the student with the research question, while in the 'purest' form of 'open inquiry', they do not, but instead provide students with "opportunities to act like scientists, deriving questions, designing and carrying out investigations, and communicating their results", stretching their disciplinary knowledge; demanding students engage in higher-order reasoning and exercise transdisciplinary competencies. Students can derive 'the burning question' themselves and from this formulate a coherent problem statement – before embarking on any problem solving. To this end, IBL may be considered a lower level of abstraction from Problem-Based Learning. Design Thinking (Brown, 2019) can dovetail neatly into the IBL process; taking students from wicked, real world research concept to well-defined problem statement through a cyclical and empathetic process of exploration and understanding of stakeholder/user needs that leads them through ideation, design, prototyping and implementation of an *appropriate* solution.

2.3 Research-Based Education

The roots of Research-Based Education (RBE), like IBL, lie in constructivism and active learning. Through more active engagement and partnership, students can become creators of knowledge and understanding. As Healey and Jenkins (2009) see it, they can journey from "knowledge consumers" to "knowledge producers." Griffiths (2004) separated the relationship between research and teaching into three distinct classes. "Research-led" teaching, using a traditional 'information transmission' model to ensure students acquire knowledge that is derived from current disciplinary research, with a focus on understanding research findings rather than research processes. "Research-oriented" teaching, includes acquisition of inquiry skills and methods, as well as disciplinary research knowledge. "Research-informed" teaching "draws consciously on systematic inquiry into the teaching and learning process itself". Most relevant here is "research-based" teaching, where the curricular focus is on 'learning by doing' with IBL as a key constituent.

3. EDUCATION FOR SUSTAINABLE DEVELOPMENT

UNESCO define Education for Sustainable Development (ESD) as "the process of equipping students with the knowledge and understanding, competencies, skills and attributes needed to work and live in a way that safeguards environmental, social and economic wellbeing, both in the present and for future generations." At a global level, UNESCO have driven the ESD agenda since the early 1990's, including their promotion of the UN Decade for ESD, followed by a Global Action Plan on ESD, the explicit inclusion of ESD in SDG 4 – Quality Education, and most recently their 'ESD for 2030 framework' (UNESCO, 2019). Sitting within ESD is Climate Education (CE), which "seeks to equip learners with the transferable skills they need to respond to a wide variety of complex, dynamic challenges including but not limited to the climate crisis" (Thew et al, 2021). Therefore, the aspiration for ESD (and CE) is that it becomes mainstreamed within HE. This means going further than creating and offering individual degree programmes or specialist courses on sustainable development and climate change, but instead ensuring ESD is ubiquitous and woven into the fabric of our formal, informal and subliminal curriculum (existing and new), our teaching

practices, course approval, quality assurance and review processes and our institutional governance structures to create the enabling environment that can empower teaching staff, with suitable CPD training and support, to actively engage with ESD.

The distinction often made by the ESD community with regards to the prepositions 'for' and 'about' and how they relate 'education' to 'sustainable development' is designed to emphasise the active, participatory purpose of Education FOR Sustainable Development. Considering this from a pedagogical perspective, Kreber (2009b) might consider Education ABOUT Sustainable Development as treating 'Sustainable Development' as a *subject* that "we look at", that can be learned "principally through extensive reading, listening and memorising", and delivered through a normative transmissive, didactic approach to teaching and learning. However, Education FOR Sustainable Development asks more of the student. It asks them to treat Sustainable Development not exclusively as a *subject* to be looked at but as a *challenge* to be met. It seeks to connect the student to the subject matter or 'challenge', not just cognitively, but emotionally and practically too. It asks the students to use their learning usefully and purposefully to make a difference; to advance the sustainable development agenda as part of their learning, and advance their learning as part of the sustainable development agenda. It asks them to do so, by developing and applying not only their disciplinary knowledge, but also the transdisciplinary competencies required to meet this 'challenge' now and forever, and as part of their personal, civic and professional lives.

3.1 Political driver for ESD

UNESCO's 'ESD for 2030 framework' was adopted by 80 government ministers when they signed the Berlin Declaration on Education for Sustainable Development (UNESCO, 2021). The terms of this global declaration were subsequently incorporated in the Co-Chairs Conclusions of Education and Environment Ministers Summit at COP26 committing governments to "the integration of sustainability and climate change in formal education systems, including as *core* curriculum components, in guidelines, teacher training, examination standards and at multiple levels." The UK draft Climate and Sustainability Strategy for the Department for Education also "puts climate change at the heart of education" and set out the UK's vision of becoming "the world-leading education sector in sustainability and climate change by 2030."

3.2 HE sectoral drivers for ESD

The current review of all subject benchmark statements by the QAA, which "describe the nature of study and the academic standards expected of graduates in specific subject areas" and which "show what graduates might reasonably be expected to know, do and understand at the end of their studies" now requires consideration of how practice within disciplines addresses wider social goals. Made explicit in this is how ESD is being embedded at degree programme level across all disciplines, thereby providing a clear sectoral driver for ESD (QAA, 2022). In addition, the QAA and Advance HE Education for Sustainable Development Guidance (QAA, AdvanceHE, 2021) highlights how ESD requires preparing students for a complex world, and the positive role that active and experiential teaching and assessment practice can have in achieving this. However, this requires staff training, development and ongoing support to ensure they are encouraged and equipped with the pedagogical approaches and tools they require to confidently embrace ESD in their practice, and engage effectively with students within and across disciplinary boundaries. This has been recognised nationally through the inclusion of "Education for Sustainable Development to inform practice" as one of five core knowledge areas for HE staff development in the draft

revision of the AdvanceHE UK Professional Standards Framework (PSF). This mandates that Universities explicitly incorporate ESD into staff development programmes. Student-centric drivers such as the SOS-UK Responsible Futures accreditation programme, which is gaining membership and momentum, is another force advocating for the mainstreaming of ESD in HE, and in time THE SDG rankings criteria will follow suit. Similarly, bodies such as the Environmental Association for Universities and Colleges (EAUC) represent a national network, coordinating collective action on mainstreaming ESD, having called upon the Scottish Higher Education Enhancement Committee (SHEEC) to ensure University governance and enhancement process evolve to explicitly include ESD, and "ensure our students can become the future leaders and changemakers required for today's complex, uncertain world".

3.3 Engineering education drivers for ESD

The priorities of engineering bodies and academies directly influence degree accreditation criteria. This subsequently influences what its taught, the way it is taught and consequently what and how students learn, and ultimately the impact they will have on society as accredited professionals. As such, accreditation bodies have the potential to act as a powerful barrier to or enabler of education innovation. Many professional bodies are now acting as agents of change within HE for ESD, responding not only to the moral imperative or political pressure, but also to the market demand of employers and students, recognising their role as a key lever for the kind of curricular and educational reform needed to equip graduates with the knowledge, skills, attributes and competencies needed to meet these global challenges. The Engineering Council's most recently published AHEP 4 (EC, 2020), asks for programme learning outcomes to have "a sharper focus on inclusive design and innovation, and the coverage of areas such as sustainability and ethics", and emphasises that "HEIs are encouraged to make use of the United Nations Sustainable Development Goals, and Engineering Council Guidance on Sustainability in programme design and delivery." Complementing this is the introduction of the Engineering Professors' Council and Royal Academy of Engineering's Engineering Ethics Toolkit (EPC, 2022), which has been designed as a growing resource to "help engineering educators integrate ethics content into their teaching…including how engineering students need to see ethics in action".

4. VERTICALLY INTEGRATED PROJECTS – RESEARCH-BASED EDUCATION FOR SUSTAINABLE DEVELOPMENT

One very pertinent and practical question remains around the mainstreaming of ESD – "what can HEIs do to guide and support their students to make this cognitive, emotional and practical connection to sustainable development as a core part of their formal education?" There may be a variety of pedagogical tools and methods capable of doing so, such as storytelling, Living Labs, role-plays, field trips, work placements, community projects, gamified workshops, collaborative, interdisciplinary working. The University of Strathclyde has had significant success through its VIP4SD programme, which aligns interdisciplinary RBE with Agenda 2030 and the UN SDGs to embed Research-Based Education FOR Sustainable Development (RBESD) in its curricula.

The VIP model for embedding RBE in HE was developed initially at Purdue University and then at Georgie Institute of Technology (Strachan et al, 2019). A novel feature of VIP is that undergraduate research teams, led by academics, consist of students from all year groups, which opens up unique opportunities for intra and inter-year undergraduate research collaboration and peer-to-peer learning. Teams can also be 'horizontally integrated' across faculties, enabling

interdisciplinary collaboration between academics and students. From the individual student perspective, VIP4SD enables them to work continuously on the same project (gaining academic credit and developing their expertise) for a minimum of two years; partnering with academics and their peers from different year groups and disciplines on long-lasting, bold and ambitious global research challenges underpinning the SDGs, extending beyond their own University lifecycle. From a research project perspective, this "vertically integrated" dimension ensures a constant throughput of students is maintained, where "new generations" of students joining the team can build on the successes of, and learn lessons from, students who have gone before them (Strachan et al, 2019) and set the directions for those that follow, as they actively engage in longitudinal, interdisciplinary discourse and research, in a manner that is not traditionally made available within HE to undergraduate students. From a programme perspective, this develops a growing and lasting student community of practice, with the opportunity to engage students on the type of collaborative, interdisciplinary working required of these SDG research challenges; providing a unifying sense of purpose as a programme and community to advance Agenda 2030. VIP4SD also raises the learning stakes, stimulating students to look beyond their academic motives to a more altruistic one of serving stakeholders and communities; inspiring students to a deeper level of learning and understanding of their disciplinary subject matter (and its relevance to society). The learning experience here emphasises how critical interdisciplinary collaboration will be in meeting these challenges, and the value of transdisciplinary competencies. The VIP4SD (2022) website offers a list of example projects.

Baxter Magolda (2009) points out that traditional teaching environments and methods often result in socialising students to become reliant on authorities and not take initiative for their own learning, or self-authorship. Similarly, educators are often socialised to function as authorities with minimal expectation to share authority with learners. In the spirit of SDG 17 'Partnership for the Goals', the VIP4SD programme purposely flips this traditional educator/learner relationship, fostering an inclusive, cooperative and student-centred learning environment where students can be "guided through the transformation from authority dependence to self-authorship", which Baxter Magolda suggests as being another "primary challenge for 21st century education." Indeed, VIP4SD will not function effectively either as a pedagogical or research instrument without this. To achieve this, it follows the key principles of Magdola's Learning Partnership Model, which requires educators to validate the learner's potential to construct knowledge and their own beliefs and opinions; and sets out the process as one of mutual knowledge construction.

5. CONCLUSION

Historically, the sustainability strategies of UK HEIs have focused primarily on the green transformation of their campus estate and more recently on fossil fuel divestment; however, as sustainability becomes a fundamental tenet of higher education, there is growing need for a more holistic approach to embedding sustainability practices across all of the traditional University pillars of research, knowledge exchange and of course education.

The QAA and AdvanceHE's (2021) Education for Sustainable Development Guidance outlined that ESD is not just about 'tweaking curricula' to include environmental or sustainability topics, but about actively integrating the principles and practices of sustainable development into all aspects of education. Exposure to, or uptake of ESD at University should not be an attribute that distinguishes students competing in the graduate market, offering a competitive edge toon one over

another. It should be a standard provision for all students; ensuring consistent levels of sustainability literacy and competency attainment. This requires a whole-institution approach to sustainability and ESD that is inclusive of all students. Only then can individual HEIs, and the sector as a whole, confidently claim to have mainstreamed ESD.

The conversation on climate mitigation has focused on measures such as carbon pricing, ending fossil fuel subsidies, land use, sustainable cities, circular economies, energy efficiency and renewable energy, and on the need for systemic change in sectors like energy, transport, industry and agriculture. There is another sector, that paradoxically is itself in need of systemic change to ensure equivalent systems change can be delivered in others. Perhaps the most important climate mitigation measure we can put in place, or action we can take to save our planet, is in the changes we make to our education system. From an engineering and technological perspective, the International Energy Agency (IEA, 2022) noted that "in 2050, almost half of the [required] CO2 reductions will come from technologies that are currently at the demonstration of prototype phase", and are therefore at risk of being unable to scale to the level required to meet our global climate targets by 2050. Who is required to develop these nascent technologies, their implementing policies and the viable businesses around them? Indeed, who will be responsible for designing and implementing the numerous other mitigation and adaptation measures needed to meet these global challenges at the scale and pace required? It will be 21st century graduates, and they need a HE sector that is itself equipped to equip them with the knowledge and understanding, competencies, skills and attributes fit for this purpose. This requires adaptations to existing approaches and the introduction of new ways of teaching and learning needed to deliver ESD. Unfortunately, there can be a frustrating latency between external signals for change and the ability of HEIs and the sector as a whole to respond to them (Thew et al, 2021), but time is not on our side.

This paper has shown through the VIP4SD case study how practical change is happening, though perhaps not fast enough across the HE sector. However, also highlighted are drivers that it is hoped will expediate the kind of curricular and educational reform required to mainstream ESD and ensure that Universities not only prepare students for the world of work; now, but more than ever, ensure they prepare them for the work of the world (Porritt, 2012).

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