Towards Integrated Engineering Curricula: South African Case Studies in Context with UCL's IEP Approach

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Abstract

Engineering education in South Africa faces persistent challenges, including diverse student preparedness, limited resources, and high dropout rates. This paper presents a project that responds by supporting national curriculum transformation through integrated learning approaches that embed both technical and professional competencies. In collaboration with University College London (UCL) and 16 South African universities, the project explores how global models can inform local curriculum design without direct replication. This paper examines four institutional case studies using Harden's (2000) integration ladder and Fogarty's (1991) curriculum integration models to map intended and actual integration practices. The frameworks offered a structured tool for comparative reflection and opened up strategic conversations about future directions. However, several limitations were noted: the models do not fully accommodate the interdisciplinary nature of engineering, assume a linear progression not always observed in practice, and focus on individual teaching rather than program-level design. Despite these challenges, the mapping process helped leaders of the four case study institutions herein critically reflect on where they are, where they intend to go, and how integration frameworks could evolve to remain relevant in diverse and complex educational contexts.

Keywords: Curriculum Integration, Employability Skills, Problem-based Learning

1 Introduction

Engineering education worldwide faces increasing pressure to equip graduates with both technical expertise and broader professional competencies (Mitchell et al., 2021). The traditional model—where early years focus on disciplinary fundamentals and professional skills are addressed separately—has been criticized for failing to develop adaptable engineers who can navigate complex socio-technical challenges (McMasters, 2004; Spinks, Silburn, & Birchall, 2006; Rauhut, 2007). In response, universities are restructuring curricula to integrate technical knowledge with interdisciplinary problem-solving, sustainability, and industry engagement (Mitchell et al., 2021; Hattingh & Inglis, 2024).

In South Africa, high dropout rates, varying student preparedness, and resource constraints pose additional challenges, requiring innovative curriculum strategies to support student success (Hattingh & Inglis, 2024). The *Transforming Systems through Partnerships - Innovative Engineering Curricula (TSP-IEC)* project, a national initiative involving 16 universities, aims to reimagine engineering curricula through integration, emphasizing sustainability and contextual problem-solving. This project aligns with international models such as UCL's Integrated Engineering Programme (IEP), which introduced a faculty-wide shift towards problem-based learning, employability skills, and interdisciplinary collaboration (Mitchell et al., 2021).

This study examines curriculum integration efforts at UCL and three South African universities—University of Pretoria (UP), University of Cape Town (UCT), and Cape Peninsula University of Technology (CPUT). Using Harden's (2000) integration ladder and Fogarty's (1991) curriculum integration models, as correlated by Husain et al. (2020), we explore how integration unfolds in diverse contexts, assessing intended designs versus current practices. The analysis also evaluates these models' applicability and limitations in capturing curriculum transformation complexities, contributing to the discourse on adapting integration frameworks for varied educational settings.

2 Literature

2.1 The Concept of an Integrated Curriculum

The need for curriculum integration has emerged in engineering education reform, with industry, professional bodies, and governments advocating for graduates who can bridge technical expertise and professional competencies (Mitchell et al., 2024; Spinks, et al., 2006; Rauhut, 2007). Traditionally, engineering curricula have been discipline-siloed, emphasizing mathematics and science fundamentals in early years and technical specialization later (Hattingh & Inglis, 2024). This fragmented approach has been criticized for failing to prepare engineering students for interdisciplinary, complex problem-solving (Graham, 2012).

Efforts to integrate curricula began in the 1990s, with research highlighting the need to embed communication, teamwork, creativity, and hands-on experience into engineering programmes (Shaeiwitz et al., 1994; Olds & Miller, 2004; Tryggvason et al., 2001). However, integration often remains limited to higher-year capstone projects, and is not embedded throughout the curriculum of an undergraduate degree program (Bailey and Aronson, 2005).

Institutions leading in curriculum integration include MIT's NEET program, which bridges theory and practice through interdisciplinary, project-based learning (Crawley, 2018); Tecnológico de Monterrey, where challenge-based learning fosters technical and professional skills for sustainability challenges (Caratozzolo & Membrillo-Hernández, 2021); and UCL's Integrated Engineering Programme (IEP), which embeds problem-solving, teamwork, and employability across eight departments, impacting nearly 10,000 students since its inaugural year in 2014 (Mitchell et al., 2021). These cases demonstrate that large-scale curriculum integration is achievable providing valuable insights for curriculum transformation in South Africa (Hattingh & Inglis, 2024).

2.2 Frameworks for Curriculum Integration

Harden's (2000) integration ladder and Fogarty's (1991) curriculum integration models are structured frameworks that define varying levels of integration. Husain et al. (2020) correlate these models to illustrate that curriculum integration is not binary, but rather a continuum, ranging from isolated disciplines to fully transdisciplinary learning experiences (Harden, 2000; Fogarty, 1991) as shown in Table 1:

Table 1: Models of integration (Husain, et al., 2020).

11 Steps of the integration model (Harden, 2000)	**Common Description**	**10 Ways to integrate curricula (Fogarty, 1991)**
Isolation	Various disciplines/departments organize their teaching without considering other departments or subjects	The fragmented model
Awareness	Teacher is made aware of what is covered in other subjects through appropriate documentation about aims and objectives of each course	
Harmonization	The disciplines remain separate but the teacher may make explicit connection within the subject areas to other subjects	The connected model
Nesting (Infusion)	The teacher targets within a subject based course, few objectives relating to the other subjects. Contents drawn from different subjects are used to enrich the teaching of a particular subjects	The nested model
Temporal coordination	Related topics within a subject are taught separately but are sequenced/arranged at the same time in consultation with other subjects.	The sequenced model
Sharing	Two disciplines may agree to plan and jointly implement a teaching program using overlapping concepts and ideas as organising elements	The shared model
Correlation	Within the subject based framework, integrated teaching sessions are introduced which bring together areas of common interest in each subject.	
Complementary programme	It has both subject based and integrated teaching. The basic difference with correlation in that the percentage of integrated sessions are increased.	Webbed
Multidisciplinary	The step brings together a number of subject areas in a single course with themes, problems or issues as the focus of teaching. The subject discipline still preserves their identity and demonstrates how they contribute to the understanding of the theme or problem.	
Interdisciplinary	The subject/discipline boundaries become blurred. There may be no reference to individual subjects or disciplines as they are not identified in the timetable. Interdisciplinary teaching implies a higher level of integration, with the content of all or most subjects combined into a new course with a new menu.	The integrated model
Transdisciplinary	There are no subjects or disciplines. There is only one subject for education, and that is Life in all its manifestation. The teacher provides the framework of learning opportunity and the integration takes place in the mind of the students based on situations of the real world.	Immersed

These models, as represented by Husain et al. (2020) and explored in this paper, provide a useful lens for evaluating curriculum integration efforts, guiding institutions in mapping progress and designing scalable curriculum changes.

3 Context and Purpose

The TSP-IEC project is a national, multi-institutional initiative in South Africa, that aims to transform engineering education by integrating technical skills with professional competencies through active learning approaches. The project team formally includes 12 South African universities and partners with UCL to leverage their experience in integrating curricula. In 2019, the project lead visited UCL to explore their Integrated Engineering Programme (IEP), and subsequent visits by the national TSP-IEC team occurred in 2023 and 2024, focusing on observing and adapting UCL's curriculum integration strategies to their local South African contexts.

4 Method

This qualitative multiple-case study explores curriculum integration across four engineering programs—UCL, UP, CPUT, and UCT—using Harden's (2000) and Fogarty's (1991) models. Curriculum leads rated their programs against integration levels in a shared excel spreadsheet, comparing intended design with current practice. Follow-up discussions helped identify gaps, patterns, and context-specific adaptations. Rather than assessing integration in isolation, the study maps how each institution navigates alignment between theory and implementation. It also reflects on the models' relevance, suggesting that adaptation is needed to suit the realities of engineering education across diverse institutional settings.

5 Case Studies

Implementing an integrated curriculum requires pedagogical innovation and institutional change. This section highlights how four institutions are combining technical content with professional competencies, interdisciplinary learning, and contextual problem-solving.

University College London (UCL)
UCL's IEP, launched in 2014, embeds project-based learning, applied mathematics, contextual and authentic learning, interdisciplinarity, teamwork, and employability skills across eight departments (Mitchell et al., 2021). UCL's experience shows that large-scale integration requires coordinated faculty engagement and a flexible model that aligns disciplinary depth with interdisciplinary learning. Key features include:

- Disciplinary and interdisciplinary design projects and scenario weeks that connect theory to real-world challenges
- Explicit and contextualised teaching of technical and transversal skills
- Active flipped scenario-based learning as a basis for the core applied mathematical curriculum
- Flexible delivery across departments
- Interdisciplinary Minors and a systems-thinking approach

University of Pretoria (UP)
UP's integrated first-year curriculum spans seven engineering departments, combining foundational modules—maths, science, engineering science, and professional orientation. UP's design integrates professional skill development alongside disciplinary learning, ensuring both technical and societal relevance. Key features include:

- Contextualized mathematics and coding
- Alignment of shared professional competency modules over six semesters
- Development of professional competencies through Engineers Without Borders (EWB) challenges and community engagement

Cape Peninsula University of Technology (CPUT)
CPUT's integration spans the first and final years. This two-stage integration links foundational learning with socially engaged engineering practice, ensuring students gain core competencies and engage with real-world challenges. Key features include:

- The First-Year Experience (FYE) integrates nine core modules with a focus on academic and professional competencies, including SDG themes across departments
- The Final-Year Integrated Learning Programme (launching in 2025) offers design challenges and entrepreneurship modules, simulating a pre-industry semester for students not in WIL

University of Cape Town (UCT)
UCT's Civil Engineering programme (2025) introduces project-based learning while reducing student overload. Key features include:

- An introductory semester project addressing local challenges such as informal settlements, integrating ethics, design, teamwork, and communication
- Twelve interdisciplinary projects connected to disciplinary courses
- Integration of programming, data science, and professional practice content
- Dedicated project weeks per semester for deep, uninterrupted engagement

These case studies show that integration takes diverse forms, but all institutions share a commitment to contextual relevance, professional competence, and alignment with industry needs.

6 Discussions

6.1 Practices and Language Across Integration Models

Both Harden's (2000) Integration Ladder and Fogarty's (1991) Ten Ways to Integrate Curriculum models present integration as a continuum, Fogarty's language draws from teaching practice and learner experience (e.g., "webbed," "threaded," "immersed"), whereas Harden's is more institutional and structural in tone (e.g., "correlation," "multidisciplinary," "transdisciplinary").

Across the four case studies, curriculum integration efforts span multiple points on both models, often simultaneously. UCL's IEP reflects elements of *harmonization*, *complementary programmes*, and *interdisciplinary* integration, mapping closely to Fogarty's *shared* and *integrated* models. Similarly, UP's common first-year structure aligns with *temporal coordination* and *nesting*, while its professional stream design matches Fogarty's *webbed* model. CPUT and UCT, at earlier stages of implementation, show practices consistent with *awareness*, *harmonization*, and emerging *multidisciplinary* approaches.

This comparison surfaced shared practices across all four cases:

- A strong emphasis on first-year structural integration (UP, CPUT, UCL)
- Project-based and socially contextual learning (UCT, CPUT)
- Integrated professional competencies (all cases, particularly GA6–11 in South Africa)
- Use of coding and data science to modernize the disciplinary core (UP, UCT)

Despite these overlaps, institutional language diverges. Some institutions foreground graduate attributes (UP, CPUT), while others lean on pedagogical terms like "scenario weeks" (UCL) or "interdisciplinary projects" (UCT). This variety highlights how different languages of integration reflect institutional culture and constraints.

7 Conclusion

Mapping the programs using Harden and Fogarty's frameworks offered a valuable lens for shared reflection and comparative analysis. It helped each institution position its integration efforts along a common continuum, prompting strategic conversations about future directions. However, the exercise revealed some limitations.

The frameworks are largely discipline-blind and do not account for how knowledge behaves across fields. In engineering—a multidisciplinary domain—transdisciplinary integration (e.g., Step 11) is less common and often less desirable than in more unified disciplines like medicine. Institutions noted that moving "up the ladder" may not always be appropriate, and that depth must be balanced with breadth depending on program goals. Many programs also resist linear categorisation. Characteristics from multiple levels often co-exist, suggesting that integration is better viewed as a spectrum than a strict progression. Additionally, while the frameworks focus on individual teaching practices, participants found more value in using them to reflect at the program level. Overall, the frameworks served as a useful conversation starter—enabling institutions to reflect on where they are, what's possible next, and how their integration efforts align with broader curriculum change.

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