EMBEDDING THE SOCIAL SCIENCES IN ENGINEERING EDUCATION: COLLABORATION WITH A POLITICS DEGREE

Susan Kenyon

Faculty of Science, Engineering and Social Sciences, Canterbury Christ Church University.

ABSTRACT

This paper reports reflections on the successful adaptation of the CDIO pedagogy to a module offered as part of a Politics and International Relations (IR) degree. CDIO has been highly successful in engineering education, enhancing engagement, attainment, satisfaction and employability, by enabling students to learn engineering *science* through engineering *practice*. The potential to achieve similar outcomes in *political* science, through *political practice*, led the author to develop the Transport: Politics and Society module. With a focus on transport studies, a subject that is naturally interdisciplinary in both academic study and industry practice, this module presents an ideal opportunity for collaboration between engineering and the social sciences. As such, this paper describes the module curriculum, considering content and pedagogy. The paper considers if the format and content of this module could appeal to engineering and social science students alike, enabling engineering graduates to understand and respond to the changing cultural, social *and political* context in which they operate, whilst providing social scientists with invaluable insights into and connection with industry and the workplace. The paper offers this module as a template which, if implemented within engineering programmes, could support the goal of furthering the aim of CDIO 3.0 to develop, embed and enhance the role of the social sciences in engineering education (Malmqvist et al, 2022).

KEYWORDS

Politics; Social science; Sustainability; Transport; Standards 1, 3, 7, 8.

INTRODUCTION

Holzer et al (2016), citing Lyman, suggest that the need for the inclusion of the Social Sciences and Humanities (SSH) in engineering education has long been recognised. However, there is agreement in the literature that, in practice, this idea has, in the main and to date, been 'more of a politically correct statement than an actual policy' (Marcone, 2022: 2).

The addition of '1.4 Knowledge of Social Sciences and Humanities' to the CDIO Syllabus v.3.0 (Malmqvist et al, 2022), alongside the acknowledgement of the importance of these disciplines in the revisions to the sustainability and acceleration themes, represents a clear break with this tradition. Syllabus 3.0 represents a step-change in engineering education, by embedding SSH,

if not in *policy*, in a close approximation of the same, namely, a set of guiding principles and distinguishing features that should underlie all engineering programmes.

Whilst not prescriptive, the CDIO Syllabus guides the development and delivery of engineering programmes at 196 Universities, across the globe (CDIO.org., Nd). As these programmes adapt to Syllabus 3.0, engineering education will transition from the concept of knowledge as being bounded by the engineering discipline, towards a more holistic, fundamental concept of knowledge and a recognition that knowledge, skills and attitudes from disciplines outside of the engineering sciences are central to preparing students to be effective engineering practitioners, on graduation.

This paper seeks to contribute to the debate on the operationalisation of Syllabus 3.0.

The paper responds to the call issued by Josa and Aguado (2021) for research to (1) examine *how* to incorporate SSH into engineering and (2) to identify which *content* areas – knowledge, skills, attitudes – within the SSH should be prioritised in engineering education. To this end, the paper reflects on the highly successful adaptation of the CDIO pedagogy to a module offered as part of a Politics and International Relations (IR) degree.

With a focus on transport studies, a subject that is naturally interdisciplinary in both academic study and industry practice, the topic of this module presents an ideal opportunity for collaboration between engineering and the social sciences. In response to Josa and Aguado's first call, the paper considers if the *format* of this module may be a suitable template for the incorporation of SSH into engineering. In response to the second, the paper considers the *content* of the module and the extent to which this contributes the *knowledge, skills and attitudes* that should be prioritised in engineering education.

The paper progresses through the following sections. First, a literature review, where the context is presented, considering the rationale for including SSH in engineering education, an overview of potential pedagogic models and an overview of subject content. Next, the Transport: Politics and Society module is presented, including pedagogy, content and outcomes. Discussion of the potential adaptation of the module to engineering education follows. The paper concludes with a consideration of the limitations of this research and suggestions for future studies.

CDIO 3.0: DEVELOPING, EMBEDDING AND ENHANCING THE ROLE OF SOCIAL SCIENCE IN ENGINEERING EDUCATION

Why Include Social Science in Engineering Education?

The primary role of engineers is to analyse, design and build to meet the needs of society (Wang et al, 2022). To be successful in engineering practice, engineers must understand the needs of society. They must connect with the day-to-day life of the community in which their decisions are to be implemented. This requires skills, knowledge and attitudes that are more commonly taught in the social sciences.

Thus, Josa and Aguado state: 'it is indispensable that engineers have knowledge in SSH [social science and humanities] to allow them to make decisions more perceptively, realistically and critically' (2021: 1). Marcone (2022) goes further: 'Without humanities and social sciences disciplines, the recognition of actors and motivations will be poor, generic, and based on

prejudgments, focusing on the concrete and evident and limiting the definition of the problem to only a few dimensions.'

Malmqvist et al (2022) highlight the growing importance of the social sciences in engineering education and practice, in light of a rapidly change social context for engineering. The authors note three 'external change drivers', the nature and impact of which can only be fully understood through a deeper understanding of society, to be gained through the social sciences, namely: sustainability; digitalisation; and acceleration. For Ashby and Exter (2019), these drivers are highlighting new problems for engineers, which cannot be solved by one discipline alone but, rather, require an interdisciplinary approach.

Juraku's reflections on nuclear engineering provide perhaps the most compelling case for the integration of social science into engineering.

> Social scientific literacy is not just an "additional" component for nuclear engineers. Rather, it is one of the most "essential" parts of engineering competences and practices... Social-scientific literacy is not a tool to manipulate public sentiment, rejecting their voices. It is a method to listen to it carefully, to find and grasp needs in society, to suggest engineers' proposal to society in humble and sincere manner and to collaborate with other stakeholders than nuclear engineers' 'old friends'. Engineers can take its advantages to make their thoughts and practices more open-minded ones… Return of diversified and independent nuclear engineers is now being waited by society.
> Juraku, 2016: 403-410.

Including Social Sciences: Potential Pedagogic Models

Josa and Aguado (2021) present three potential pedagogic models for including the social sciences in engineering education.

The first and most desirable involves integrating the social sciences into every aspect of engineering education, which the authors term 'transversal' integration. The second is to introduce general social science subjects into the curriculum – for example, including a module on psychology, or sociology, or politics. Juraku et al (2016) describe the PAGES initiative to include the social sciences in nuclear engineering education took this 'addition model', where elements of the social sciences were added to the curriculum, rather than fully integrated and embedded into all aspects of education. Marcone (2022) highlights this approach, using interdisciplinary projects.

The third option identified by Josa and Aguado is to introduce specific social science subjects, for example transport inequality, or environmental justice. Whilst Holzer et al (2016) caution against viewing the social sciences as 'add ons to an already crowded curricula rather than substantially integrated components' (ibid: 4), Josa and Aguado suggest that the current lack of social science knowledge among students and faculty members is likely to prevent this strategy, in the short to medium term.

Including Social Sciences: Content

Finally, it is important to recognise that the social sciences encompasses many disciplines. Marcone (2022) is clear in the content that the social sciences can usefully contribute.

- Soft skills, to enhance the performance of engineers, including communication.
- Providing a social context, a different perspective from which engineers can critique and test their solutions, before implementation. In this sense, the social sciences enter education at the end of product design.
- Providing a social context from which to conceive problems and solutions, fully integrating skills, knowledge and attitudes from the first approach to the last.

This paper suggests a potential module which could be introduced into the engineering curriculum, following the approach to introduce a specific subject, viewed through a social science lens, with social science content fully integrated from concept to operation. It is to this module that this paper now turns.

TRANSPORT: POLITICS AND SOCIETY

Development

CDIO has been highly successful in engineering education at Canterbury Christ Church University (CCCU), enhancing engagement, attainment, satisfaction and employability by enabling students to learn engineering *science* through engineering *practice* (Crawley et al, 2007).

The global success of this active, team-based pedagogy, which accepts, values, includes and encourages all students in the learning community, has led a number of authors to experiment with its adaptation in other disciplines. For example, Malmqvist et al (2016) highlight application in business, chemistry, education, food science and music. Tangkijviwat et al (2018) consider advertising, cinematography, design, media, photography, public relations. Tholler and Rian (2020) review application to digital media, hotel management, health & beauty and Thai traditional medicine courses. Further papers consider CDIO in accounting (En et al, 2022), events management (Ng and Tan, 2022), sustainability (Cheah, 2022) and teacher education (Bang et al., 2022).

The above papers highlight that the CDIO pedagogy has been successfully adapted to non-engineering programmes. However, there are no documented applications to Politics and International Relations (IR). As such, this paper reports the first known adaptation to Politics/IR.

The module aimed to achieve similar outcomes in *political* science, through *political practice*. This inspired the creation of a new module, Transport: Politics and Society, with the Politics and IR framework of degrees.

With a focus on transport studies, a subject that is naturally interdisciplinary in both academic study and industry practice, this module presents an ideal opportunity for collaboration between engineering and the social sciences. As such, this paper now turns to describe the module curriculum, considering content and pedagogy.

Content

The starting premise of the module is that we are a society that needs to move. In the UK and many countries across the globe, we live in a built environment in which physical mobility is both necessary and expected to participate in activities. Economic, planning, social and transport policies have resulted in living environments and activities that are dispersed across

large, ever-increasing distances. Our society and culture, our biology and psychology, act to reinforce this mobility dependence in our hypermobile societies.

As a result, to participate in the activities that we need to take part in to be included in the society in which we live – including education, employment, leisure, shopping, social networks – we need to be able to travel, usually by motorised mobility. However, a substantial proportion of us are not able to travel as much as we need to, to take part in the activities that enable us to be included in the society in which we live (Kenyon et al, 2002; Lucas, 2019). This results in *mobility-related social exclusion*.

The link between mobility and social exclusion is well-established. Across the globe[1], studies have confirmed the existence, experience and effects of mobility-related exclusion (MRE):

> The process by which people are prevented from participating in the economic, political and social life of the[ir] community, because of reduced accessibility to opportunities, services and social networks, due in whole or in part to insufficient mobility in a society and environment built around the assumption of high mobility.
> (Kenyon et al, 2002: 210-211)[2].

This is experienced most keenly by those experience disadvantage, inequality and/or exclusion in other ways: children; disabled people; non-drivers; people of colour and other minority ethnic groups; people with a low income; older people; women.

In this sense, some have *too little mobility*, which results in exclusion from activities, including education, employment, healthcare, family and friends, leisure, shopping and other activities that are critical to social development (Kenyon, 2015).

But the solution to the problems caused by too little mobility cannot be to increase mobility, for two key reasons. First, studies suggest that when we increase mobility, we decrease accessibility (Kenyon, 2015), to the extent that mobility and accessibility are described by Ross (2000: 13) as 'the yin and yang of planning'.

Second, increasing mobility is environmentally problematic. Transport is a primary contributor to climate change and environmental harm. Transport accounts for around 16% of global Greenhouse Gas (GHG) emissions (Ritchie et al, 2020). In the UK, approximately a quarter of GHG emissions are estimated to be from the transport sector (DBEIS, 2022). Transport has more far-reaching implications for the environment, causing environmental harms including: airborne particulates and other air pollutants; community bifurcation and isolation; ecosystem damage; land take; noise pollution; resource use; visual pollution; and water pollution.

In this sense, we have *too much mobility*. Increasing mobility to tackle the problem of too little mobility will worsen the problem, in the longer term.

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[1] Knowles (2019) and Lucas (2019) provide an overview of the growth in the field of study since 1993, largely in the UK and USA. To illustrate global reach, in the first six months of 2022 alone, the literature has expanded to include 17 papers on transport and social exclusion, reporting studies from every inhabited continent: Africa (Castro et al, 2022); Asia (Wang et al, 2022); Australasia (Shaw and Tiatia-Seath, 2022); Europe (van Dulman et al., 2022); North America (Cooper and Vanoutrive, 2022); South America (Ospina et al, 2022).

[2] Whilst this definition has been expanded in recent years to include consideration of the unequal impact of negative transport externalities (Kenyon, 2015), this paper focuses on MRE as a *lack of access to participation*, as defined above.

So, what do we do, when policies conflict in this way? Do we tackle exclusion, or environment? Who do we prioritise? Why? Do we prioritise the short term, or the long term? How? These debates lie at the core of the module content and pedagogy, to which this paper now turns.

Pedagogy

The module introduces students to the complexity real world policy practice, through an approximation of a design-build-test project, over ten weeks.

Conceive (weeks 1-4).

Students uncover the problem of transport-related social exclusion first-hand, by taking a walkabout around Canterbury city centre in the UK. Through this mini-ethnography, students observe key features in the urban environment, including a pedestrian crossing, a bus stop, a car park and an underpass. Students are prompted to consider, for example, who they can see and who they can't see in these locations; to count how long pedestrians have to cross at a pedestrian crossing; to feel how welcoming the environments are.

Teamwork begins at this first task: students explore in pairs, matched with someone who has different characteristics to themselves. This helps to illuminate the experience of transport exclusion, but it also encourages students to accept, include and value different perspectives in their 'workplace': an invaluable, real-world, employability skill.

After seeing the problem for themselves, students return to class to discuss their findings. They apply their observations, to conceive the problem of too little mobility as it affects them, or their local community.

All further learning is focused on understanding the specific problem that they would like to resolve. Individualised readings are selected for each student, based on their transport problem. Every student must report back on their reading, every week, to enable other students to learn about the problem of transport exclusion more deeply and theoretically. This develops invaluable professional skills, including communication, confidence, note-taking and reliability; and teamworking builds learning community.

Design (weeks 5-6).

At this stage, students design a potential solution to the problem of too little mobility in their community. They select the decision maker that they need to influence to resolve their problem and present a 5-minute verbal briefing, designed to appeal to their specific decision maker. This is the culmination of their learning about too little mobility and is 50% of their assessment.

Based on government guidance for briefing Ministers (Jary, 2015) and consultations with civil servants and industry, this authentic assessment (Kenyon et al., 2021) is highly employability focused, developing communication skills relevant to all manner of industries, not just in the political sphere, but also business, consultancy, civil service, local government. In combination with the second assessment, it is designed to develop industry-ready graduates, who have built employability skills through this form of work-related experience.

The assessment also shows graduates they belong in the workplace. Graduates are more employable, because they are work-ready; and they are valued and included in the workplace, because they are more able to assimilate into the workplace community.

Implement (weeks 7-10).

It is not possible for students to implement changes to the transport system. To approximate this, students critically reflect upon their proposed solution, by introducing policy conflicts. This, combined with consistent formative feedback on the proposed implementation of their solution, from the tutor and their peers, students consider what may happen if they implemented their proposed solution. First, they consider the potential negative effects of increasing mobility, considering who may be harmed by their proposal – other demographics, the environment – and the negative impact on other policies – economic, health. Second, they consider who may oppose the implementation of their solution and how they may overcome this opposition, through conflict or compromise, to influence implementation.

Operate (assessment).

Finally, students operationalise their learning, by delivering their recommendations in the form of an options and recommendations paper (Jary, 2015), targeted to meet the needs of and to influence the decision-making process of their specific decision-maker.

Through the lens of their transport problem, political decisions are brought to life: the complexity; the compromises; the consequences; the contradictions.

OUTCOMES

The approach has been very successful.

- 100% first-time pass rate for 3 cohorts (equivalent modules: 66%).
- Average mark 70% (equivalent modules: 59%).
- Substantially higher attendance, engagement and attainment, relative to other modules.
- Universal satisfaction (measured in module evaluations).
- All module graduates were in graduate employment/further study 6 months after graduating.

In addition, students' studies have been shared with stakeholders and presented at conferences, highlighting the potential for students' work to have real-world influence and impact. Topics chosen and investigated by students include:

- The impact of lack of transport on Covid-19 uptake in deprived communities;
- Necessary changes to street lighting, to enable active mobility for women;
- A business case for the provision of free transport home from a student nightclub;
- The impact of lack of transport on visitors to a care home;
- The impact of lack of transport on widening participation to Higher Education;
- Measures to enhance safety for LGBTQ+ travellers on public transport.

THE OPPORTUNITY

The success of the TPS module provides proof of concept that the CDIO pedagogy is adaptable to Politics and International Relations courses. It can confidently be asserted that successful adaptation to this social science discipline suggests that adaptation to other social science disciplines, including geography, psychology, sociology and social policy, will also be successful.

Given that this engineering pedagogy works across disciplines, could this social science content work for engineers?

With a focus on transport studies, this module presents an ideal opportunity for collaboration between engineering and the social sciences, to embed social science knowledge, skills and attitudes in engineering education.

Engineers facilitate mobility. Civil engineers design infrastructure; chemical engineers consider fuel technology; mechanical engineers design vehicles. At present, engineers design and build to the needs of society. But what if society's 'needs' are damaging and should change?

Society's demand for mobility is framed as 'need'. As such, engineers who design and build to the needs of society will continue to facilitate greater mobility. However, as discussed above, facilitating this need is environmentally damaging. It is also counter-productive, reducing rather than increasing accessibility in the longer term.

If adapted to engineering education, this module content and pedagogy would introduce engineering students to the complexity of social need. Through the lens of transport, engineering students will be exposed to and will experience the reality of political/Political decision making, learning the contested nature of need, competing interests, conflicting 'solutions'. They will reside in different environments, which reflect the complex web of stakeholders that they will encounter in their professional lives, including the communities impacted by their work and the politicians making decisions.

LIMITATIONS AND NEXT STEPS

The applicability and potential benefits of incorporating this module within engineering education is, at this stage, speculative. Success to date is proven on a single course, with 3 small cohorts (n=c.15 per cohort), at a single University. As such, generalisability to other contexts is not proven.

Next steps in this research are to adapt, implement and evaluate with larger cohorts, in different disciplines and different institutions. With this paper, the author calls for collaborators, willing and able to adapt, implement and evaluate, to expand the evidence-base and further understanding of how to further develop, embed and enhance the role of the social sciences in engineering education, furthering the aim of CDIO 3.0.

CONCLUSION

Syllabus 3.0 represents a step-change in engineering education, by embedding Social Sciences and the Humanities in the guiding principles and distinguishing features that should underlie all engineering programmes. This paper has sought to contribute to the debate on the operationalisation of Syllabus 3.0.

The paper has highlighted success in adapting the CDIO pedagogy to a module on a Politics and International Relations course. With a focus on transport studies, a subject that is naturally interdisciplinary in both academic study and industry practice, this module presents an ideal opportunity for collaboration between engineering and the social sciences.

The paper suggests that this module could be used as a template which, if implemented within engineering programmes, could support the goal of furthering the aim of CDIO 3.0. The paper offers proof of concept that the module curriculum could be effective and calls for collaboration in a range of engineering courses and settings, to further this research agenda.

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BIOGRAPHICAL INFORMATION

Dr Susan Kenyon is Principal Lecturer in Politics in the Faculty of Science, Engineering and Social Sciences at Canterbury Christ Church University. Dr Kenyon has more than 20 years' experience in travel behaviour science, in academia and industry. Dr Kenyon was Faculty Director of Learning and Teaching 2017-2021. Her tenure included the establishment of the School of Engineering, during which time she coordinated both the integration of CDIO into all Engineering and Computing courses and CCCU's successful bid for membership of the CDIO Initiative. Dr Kenyon holds a BSc Hons Politics (York), MA Dist. Environmental Politics (Keele) and PhD from the School of Engineering at the University of Southampton.

Corresponding author

Dr Susan Kenyon
School of Law, Policing and Social Sciences
Faculty of Science, Engineering and Social Sciences
Canterbury Christ Church University
Canterbury, Kent. CT1 1QU.
United Kingdom.
Susan.Kenyon@Canterbury.ac.uk.