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Leadership skills development among engineering students in Higher Education – an analysis of the Russell Group universities in the UK

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ABSTRACT

Today, the engineering landscape is continually changing, and Higher Education Institutions (HEIs) have a responsibility to design curricula that address the growing demands of various industry sectors. Likewise, the roles and responsibilities of an engineer are evolving; requiring a further broadening of the current engineering curriculum. As a profession, engineering draws upon broad interdisciplinary knowledge, and when training twenty-first-century engineers, universities should follow a more comprehensive teaching and learning approach, with a focus on both technical and soft skills including the integration of leadership into engineering curricula. However, the spectrum of engineering leadership is not well-defined. Leadership is one of the most widely sought-after skills in the Science, Technology, Engineering, and Mathematics (STEM) industries; it is, therefore, clear that more investigation needs to be carried out into this area of engineering pedagogy. One of the most distinct gaps in the literature is that there is little or no consensus on what approaches should be undertaken to integrate leadership in engineering courses by those in academia. This paper seeks to shed light on some of these gaps, with the primary objective of the evaluation of the current state of leadership education using a nation-wide sample of BEng[1] Electronic Engineering course structures and contents at Russell Group[2] universities in the UK. It highlights the case study of the University of York, where there is a strong emphasis on the integration of engineering leadership and management skills within the current BEng Electronic Engineering course structure.

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Introduction

Effective leadership is widely regarded as one of the most critical assets of any organisation in today's fast developing economic environment. An influential leader can play a pivotal role in ensuring the success of both the team and the enterprise as a whole. In STEM sectors, top firms with effective leadership are approximately 40% more productive than the rest, with operating margins between 30% and 50% higher than industry peers (Mankins 2017). The impact of effective leadership is widespread in the fields of engineering, and crucial for ensuring the competitive advantage of a firm. According to Shuman et al. (2002, 2), '*In a technological dominated world, the engineer becomes the switching point in modern industry and in society as a whole*'. It is, therefore, important to understand the core skills and competences that organisations expect from modern engineers. However, the modern global economy has rendered technical skills alone insufficient: communication, project

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management, and other leadership skills are becoming more critical than ever before (Brown 2005). The Institute of Engineering and Technology (IET), the world leading professional engineering organisation, notes how skills shortage in the engineering sector has been an ongoing problem in the UK. Their latest skills survey report

> an estimated annual shortfall of 59,000 new engineering graduates and technicians, a deficit which only continues to get worse … .recruiting engineering and technical staff with the right skills is the largest anticipated obstacle that businesses face in achieving objectives over the next three years. (IET skills survey 2019, 2)

Bayless and Robe (2010, 1) note '*Leadership skills are critical for accomplishing goals as an engineer and innovator*'. The importance of leadership skills among twenty-first century engineers was similarly emphasised by the National Academy of Engineering's report 'The Engineer of 2020' (National Academy of Engineering 2004). An engineering workforce that possesses sufficient technical and leadership skills for the future will be critical to facilitate sustainable growth in the STEM field and thus the economy as a whole. Today there is a need to transform engineering curricula within Higher Education (HE) with a particular emphasis on leadership skills. As the IET pointed out, '*We need courses that not only teach students technical skills but also develop their creativity and soft skills …* ' (IET 2019, 10). Schell and Kauffmann (2016, 3) support '*Recognition of the importance of Engineering Leadership is part of an increasing movement toward incorporation of curricular materials that promote developing engineers who meet the broad needs of today's industry*'. Kotnour and Reilly (2014) noted how many universities are now attempting to integrate leadership into the engineering curriculum. However, literature on the integration of Engineering Leadership in UK curricula and universities is scarce, with recent studies such as Kotnour and Reilly (2014), Gonzalez, Schoephoerster, and Townsend (2015), Klassen et al. (2016), Schell and Kauffmann (2016) and Kendall et al. (2018) focusing mainly on American and North American engineering curricula. Also, Kendall et al. (2018, 2) observed '*In the engineering education literature to date, there has been relatively little attention paid to the increasing importance of leadership education as an element of engineering programs'*. This paper, therefore, focuses on some of these gaps in literature.

The main objective of this paper is to evaluate the current state of Leadership Education by presenting a critical analysis of the current course content and pedagogical approaches employed by UK universities. In order to complete a feasible study, the researchers focused on one specific field of engineering – Electronics – which is one of the most popular engineering disciplines in academia and of great importance to the UK economy (RAE 2016). The paper uses a nation-wide sample of BEng Electronic Engineering course structures and contents at the Russell Group universities. The Russell Group is the equivalent of the American Ivy League of prestigious universities (The Guardian 2003) and are '*committed to providing an outstanding education and experience for their students, helping them to learn the skills they need to enter the workforce'* (Russell Group 2020). The term 'integration' in the context of this study also needs to be established. Klassen et al. (2016) identified three clusters of Engineering Leadership programmes: degrees where leadership is integrated with technical engineering courses; degrees where leadership is treated as a stand-alone subject; and degrees which engage all engineering students in leadership education. Throughout this paper, all three clusters will be considered to reflect the overall integration of leadership education in electronic engineering courses at the Russell Group universities. The analysis will be further supported by using the case study of one of the Russell group universities – the University of York.

Complexity of the leadership concept

Leadership has naturally been a topic of interest for a long time, with literature on the subject being both broad and plentiful. Despite this, there is arguably little or no consensus on an agreed definition of leadership, with Rost (1993) finding 221 definitions in over 587 publications and Winston and Patterson (2006) uncovering over 90 variables that are encompassed within the concept of leadership. Some define leadership as the: '*ability to build and maintain a group that performs well relative to its* *competition*' (Hogan and Kaiser 2005, 172)*; 'process of motivating people to work together collaboratively to accomplish great things'* (Vroom and Jago 2007, 18); *'process of interactive influence that occurs when, in a given context, some people accept someone as their leader to achieve common goals'* (Silva 2016, 3); '*influence relationship among leaders and followers who intend real changes that reflect their mutual purposes*' (Rosari 2019, 17). Yukl (2010, 21) in this context observed '*leadership has so many different meanings to people, some theorists question whether it is even useful as a scientific construct'*. Though that is not to suggest that we cannot accurately perceive or comprehend leadership, rather that we struggle to express it in its entirety within the narrow bounds of a 'definition'.

However, researchers have explored the components that can effectively illustrate the complex concept of leadership. Northouse (2010) considers four components to conceptualise the phenomenon of leadership; process, influence, group engagement, and common goals. For him, leadership is a process but not a linear one-way event. He calls it an interactive event in which influence is absolutely vital, further adding, '*Without influence, leadership does not exist'* (3). Yukl (2010) similarly puts strong emphasis on influence in his proposed concept of leadership. He defined it as '*the process of influencing others to understand and agree about what needs to be done and how to do it, and the process of facilitating individual and collective efforts to accomplish shared objectives'* (26). Yukl's definition takes into account both direct and indirect forms of influence, with the view that leadership can be shared or distributed and that more than one individual can undertake a leadership role with some form of role variations within a group. Rosari (2019, 23) agrees, '*The relationship that is leadership must be based on influence'*.

Some researchers like Hartmann and Jahren (2015) have studied leadership in the context of engineering graduate roles. They have identified five major themes that reflect engineering leadership and these include initiative/confidence, communication skills, interpersonal skills, teamwork skills, and engagement. However, there are some notable barriers to the recognition of leadership within the engineering profession. Although the roles of engineers have evolved over the years, researchers such as Kendall et al. (2018) and Rottmann et al. (2016) observed some form of resistance from engineering professionals when it comes to associating engineering roles with leadership. Rottmann, Sacks, and Reeve (2014, 2) noted '*engineering leadership will not hold as a legitimate field of study or practice until it is accepted and implemented by a critical mass of practicing engineers*'. They emphasised the need for a widespread recognition of engineering as a leadership profession. A study conducted by Rottmann et al. (2016) on a group of engineers with distinct organisational roles found that the response to the word 'leadership' varied heavily among the participants and this was primarily influenced by their roles. They noted '*engineers in different roles experience and define leadership in distinct, organizationally contextualized ways … the domains over which engineers have some degree of influence shape their definitions of leadership*' (164–165). For instance, an engineer working in a technical role used terms such as professional competence to define leadership as opposed to an entrepreneurial engineer who used terms like innovation drive and marketable change. Despite the resistance to the word 'leadership', Rottmann, Sacks, and Reeve 2018 (2014) concluded that engineers across sectors do have the potential to lead. Their analysis identified three orientations on engineering leadership – technical mastery (tendency to solve technical challenges and problems), collaborative optimisation (tendency to build, facilitate and manage high performing teams) and organisational innovation (tendency to innovate and anchor ideas towards practical realisation). Engineers embodying one or more of these orientations would be able to demonstrate the integration of the technical, creative and humanistic components of this profession. These orientations represent distinct conceptions of leadership reflecting '*engineers' professional experiences with interpersonal, team and organizational influence*' (16).

Rottmann et al (2016) recommend exposing students to the full range of career options within an organisation setting to showcase the nature of Engineering Leadership and its orientations. They reflect '*As engineering educators, we need to help our students appreciate both formal and informal modes of leadership practised by engineers in a range of organizational roles and locations. To the extent that our students expand their definitions of leadership to include collaborative, informal* *modes of influence, we will be helping them embrace the idea of engineering as a leadership profession*' (165). Therefore, in the education of leadership (outside of an organisational setting), an emphasis must be made to recognise the diverse nature of leadership and the dynamic nature of an effective leader. However, Adair (1984) maintained the stance that only skills which are teachable, testable, or can be actively developed should be a worthwhile consideration – the contrary encourages leader selection instead of leader development. According to Knight and Novoselich (2017, 45), '*leadership is important for advancing both the engineering field and for individual graduates' careers. Despite such calls to expand engineering students' leadership abilities, however, we know fairly little about the potential influences on this learning outcome*'. In this context, it is important to evaluate how leadership is viewed in the context of engineering education.

Engineering leadership in Higher Education

Modern-day engineering education has been the product of several decades of development, providing graduates with a broad range of professional and technical skills in preparation for the workplace. HEIs design specific curricula to address the demands and needs of various industry sectors. In this context, Stevens et al (2009) noted that the world of technology and innovation is constantly witnessing new changes and these have a strong impact on the engineering practices including the education and training provided by HE. Universities have a responsibility to keep their programmes and curricula up-to-date; keeping pace with the rapidly changing world of engineering. Since the 1990s and the publication of official papers such as The Green Report (USA) (1994), there has been a heightened demand for HEIs to broaden the skills taught in engineering degrees; encapsulating more elements of both leadership and management. But as Kumar and Hsiao (2007, 19) found '*Leadership is rarely discussed in traditional engineering courses'.* For them, to become a true engineering leader, students must have both technical and soft skills. Supporting Kumar and Hsiao, Bayless and Robe (2010, 1) add '*Engineering has often neglected leadership education and/or training, being seen academically as a 'soft skill' not relevant to the discipline … Most engineering curricula focus on producing technical excellence. However, technical competence is 'absolutely necessary but not sufficient' for carrying out the professional responsibilities of today's engineers*'. Also, the literature on engineering leadership is limited. As Schell and Kauffmann (2016, 3) observe, '*The concept of engineering leadership is a relatively new one in engineering education, with most publications on the topic and formal programs to develop it appearing in the last ten years*'. Rottman, Sacks and Reeve (2014, 3) point out that a lot of these publications are '*limited to authors' promotional descriptions of their own programs*'.

Seat, Parsons and Poppen (2001) noted how engineers, as a group, are often known for their ability to solve problems and their inability to work well in teams. Knight and Novoselich (2017, 44) label engineers as '*the nation's most well-equipped problem solvers*' with the growing technology-driven environment requiring them to undertake leadership roles and develop sustainable and workable solutions. Kumar and Hsiao (2007) observed that engineers generally tend to focus on technical details and in the process, they often overlook the broader picture. They further explained ' *… today's engineers are asked to do a lot more than just apply the scientific knowledge to solve practical problems. Currently, engineers hone their leadership and management skills while at work (i.e. learning 'soft skills the hard way')*' (19). A shift towards a softer side of engineering is now gradually emerging. As Stevens et al (2009, 1) explain ' *… the requirements of the engineering profession have expanded beyond its domain, blurring the boundaries between disciplines, specifically with the management and leadership fields'.* Today's engineers are expected to have a good understanding of interdisciplinary knowledge such as intellectual property rights, data protection laws, ethics and compliance and the impact of engineering towards a sustainable environment and economy. Kotnour et al (2014) reflected on the importance of engineering leaders to provide solutions to some of the key challenges we face in the world. They stated '*We need engineering leaders … Many studies have explored the role of engineers and the need to change the educational system to* *produce these engineers … the need to build worldly leadership and professional skills within the engineering profession … We need to produce the leaders who can deliver sustainable solutions to the world's biggest challenges. Creating these engineers requires a unique educational experience and environment to learn these skills'* (48). So, for training twenty-first century engineers, universities should follow a more comprehensive teaching and learning approach with a focus on both technical and soft skills. One of the approaches includes the integration of leadership in engineering curricula. A study conducted by Palmer et al (2016) on 30 North American, African and European universities noted a lack of Engineering Leadership specific degrees. 70% of the sample they studied, didn't have any form of Engineering Leadership degree however, 73.3% had some form of Engineering Leadership coursework. These authors summarise '*Within our sample, engineering leadership coursework appears to be relatively commonplace. As leadership coursework continues to spread throughout the engineering curriculum, the number of degrees, minors, and certificates may continue to increase*' (11). Ahn et al (2014) highlighted three key difficulties associated with designing Engineering Leadership based courses and these are: defining Engineering Leadership; the absence of assessment tools that exclusively assess engineering students; and limitations with training engineering faculties who could design and teach leadership courses.

Many researchers note how the spectrum of Engineering Leadership in education is not well-defined. Schuhmann (2010, 67) added '*While the study of leadership is considered to be a mature field, engineering leadership education today remains effectively undefined … There is clearly a demand for leadership development in engineering students*'. Ahn et al (2014, 117) stated '*It is important to define engineering leadership to identify the important competencies and traits that engineering leaders should possess … an operational definition of engineering leadership is needed to guide engineering faculty in their implementation of leadership activities. Also needed are tools that allow leadership program managers to assess the impact of their program or curriculum and tools that track the longitudinal development of students in engineering leadership programs'*. Paul and Falls (2015) believe that a stronger understanding of this term will help in the development and improvement of engineering leadership programmes.

It is obvious that the roles and responsibilities of an engineer are evolving, and the curricula also need to broaden in order to accommodate these developments (Bakos, 1997). A recent study conducted by Paul, Sen and Wyatt (2018) explored how leadership can be defined in an engineering context. Using a content analysis on 163 definitions, they extracted four key themes which include: leading and influencing others, personal effectiveness, engineering competency, and collaboration. They defined Engineering Leadership as '*an approach that influences others to effectively collaborate and solve problems. Engineering leadership requires technical expertise, authenticity, personal effectiveness, and the ability to synthesize diverse expertise and skillsets, Through engineering leadership, individuals and groups implement transformative change and innovation to positively influence technologies, organizations, communities, society, and the world at large*' (10).

While engineering education has evolved, the majority of the evidence of leadership integration in engineering curricula seems to be in the USA rather than Europe (Graham, Crawley and Mendelsohn (2009), Kotnour and Reilly (2014), Gonzalez, Schoephoerster and Townsend (2015), Klassen et al (2016), Schell and Kauffmann (2016) and Kendall et al (2018)). For example, one of the most prominent programmes on Engineering Leadership is the Bernard M. Gordon- MIT Engineering Leadership Programme (GEL) which supports MIT engineering undergraduates to develop and shape their skills as '*effective and impactful leaders who will be charged with solving the world's most challenging and complex problems*' (GELP- MIT, 2020). The first year is tailored to provide an introduction to leadership frameworks and models such as ethical decision-making, project engineering and systems thinking; students practice such skills through simulations, coursework, and other experiential activities. The second year uses a more personalised leadership development approach. Students work closely within, and lead, their own organisation – taking part in internship opportunities, courses on project management, and challenges of people management. Reflection is key to the learning process, students are actively encouraged to engage in self-assessments of their performance –

identifying ways to improve their competencies such as decision-making. The University of Texas at El Paso similarly offers an undergraduate programme in Engineering Leadership (E-Lead) which is meant to be a paradigm shift in engineering education. Branded as '*the first degree of its kind in the nation*', this programme mainly focuses on student's collaborative capabilities, mentoring skills and personal growth to facilitate their personal and professional achievement (E-LEAD, 2020). In order to infuse a leadership mind-set, this programme focuses on three pillars of Engineering Leadership: Character, Competence, and Capacity. It utilises flipped classroom and project-based learning which are multidisciplinary in nature. The programme advocates a '*culture where students actively contribute to their own education and where individual contributions are valued and important. E-Lead students strive for excellence because they have a sense of ownership and power over their own education*' (E-LEAD, 2020). This emphasis on practice-based learning in Engineering Leadership programme was also reported by Klassen et al (2016) to be present in some of the leading North American Universities. The success of these programmes shows the power of blending education with experiential learning and reflection, alongside opportunities to facilitate leadership capabilities and skills. In this context, Kendall et al (2018, 5) noted '*The calls for engineering education reform have led engineering educators to think more intentionally about creating learning experiences that incorporate reflective practice for students, in areas such as teamwork, communication, and lifelong learning. These areas collectively comprise not just a model of engineering leadership, but also a set of pedagogical approaches that can be used to develop an undergraduate experience that serves as a foundation for future engineering leadership development once students enter the workforce*'. UK universities such as Loughborough University and The University of Bristol, too have taken some initiatives with integrated programmes which explicitly develop leadership skills (Graham, Crawley and Mendelsohn, 2009). Other institutions are similarly following this path by creating specific programmes which implicitly integrate leadership development into existing course content (Khattak, Ku and Goh, 2012). Notwithstanding these developments, the IET and other professional bodies have found skills such as leadership, management and communication skills are still deficient in graduates and recruits (Hissey (2000), Mohan et al (2009), IET skills survey (2017, 2019)). It is no surprise, therefore, that for senior management positions, individuals with MBAs or JDs are often awarded such positions over engineers (Summers, Davis and Tomovic, 2004). Generally, the educational demands of such degrees better prepare them in communication, leadership and management; precisely the skills that are deemed deficient in engineers. Considering these apparent flaws in engineering leadership and management education, this suggests there needs to be further review into what extent such skills are developed within course curricula. Stevens et al (2009, 1) summarised '*It has become evident that there is a crucial need for change in the practice of engineering and the education of future engineers. Specifically, engineering disciplines need to be broadened and enriched to better prepare graduates for working in a constantly changing economy driven by the explosion of knowledge, globalization, and a myriad of other factors*'.

Elements of Engineering Leadership

As established by Ahn et al (2014) and Rost (1993), the act of defining leadership is problematic, and can lead to many varied interpretations. Therefore, following the propositions of Adair (1984) – that leadership education should only consider skills which can be actively developed and are to some degree testable or assessable – the authors propose the introduction of a framework in order to define the high-level concept of Engineering Leadership by its lower-level constituent and developable elements. Similar in approach to Farr, Walesh and Forsythe (1997) and their proposition of Engineering Leadership qualities. Such a proposal for defining Engineering Leadership is reductionist in its nature, with a pragmatic basis rather than solely theoretical. The framework shall henceforth be called the 'Elements of Engineering Leadership', and is defined in Table 1.

In the development of the Elements of Engineering Leadership, a range of literature was sampled in order to establish the consensus on what overarching skills contribute to effective leadership and

Table 1. Elements of Engineering Leadership.

1. Character development	Environmental considerations Ethics Professional conduct Societal impact of engineering	
2. Business knowledge	Accounting and finance Business strategies Economics Entrepreneurship Law Marketing	
3. Interpersonal skills	Communication skills	Displaying data Explanatory skills Oral communication Written communication
	Influencing others Peer evaluation	
	Teamwork	
4. Intrapersonal skills	Analysis skills Innovation Problem solving skills	
	Self-evaluation	
5. Management skills	Change management Project management Resource management Risk management Time management	
6. Study of leadership		

Engineering Leadership, or are most pertinent. Following this, it was established there were six key knowledge bases, or skill areas, which the literature recognised:

- Character development
- Business knowledge
- Interpersonal skills
- Intrapersonal skills
- Management skills
- Study of leadership

Character encompasses the moral, ethical and professional qualities which influence a leader's actions. There is no neutral ground concerning leadership ethics or values (Heifetz, 1994). And whilst agreement on conceptions of ethics, integrity, and conduct is mixed in the broader domain of leadership theory (Yukl, 2010), established expectations of engineering values, ethics, and conduct exist (Engineering Council (2016), Royal Academy of Engineering (RAE) (2017)) and should thus be considered. Engineering leaders should know and exhibit these values, assuming a '*larger role in societal leadership*' (Bonasso, 2001, 1). Further, an engineering leader should '*demonstrate a personal commitment to professional standards, recognising obligations to society, the profession and the environment*.' (Engineering Council, 2016, 28). Thus, we propose Character shall be subdivided into 4 elements: Environmental Considerations, Ethics, Professional Conduct, and Societal Impact of Engineering. Considering the principles outlined by the RAE and Engineering Council, in this context, Environmental Considerations encompasses the obligations an engineering leader has on issues concerning sustainability and the environment. For instance, opting to utilise sustainable fuels and materials, ensuring the safe disposal of hazardous waste, or the minimisation of ecological impact. Further, one may question why ethics is distinct and separate. This shall be a catch-all for all ethical topics and principles not a subset of the other elements, for example, to '*promote equality, diversity and inclusion*' (RAE, 2017, 2).

Business knowledge incorporates all of the appropriate knowledge bases required as a leader in the field of business. Mumford, Campion and Morgeson (2007) outlined an understanding of business skills to be vital for organisational leaders, the same is also said to be true for engineering leaders (Salmani and Bagheri (2010), Crumpton-Young et al (2010), Hissey (2000)). In order to subdivide this category, we shall consider the commercial knowledge bases key for an engineering leader within an organisation. Hissey (2000) found that engineering industry leaders over various continents believed ''*high-potential' engineers, who rapidly rise within their organisations to positions of great prominence and leadership'* (1) should, but don't, possess *'marketing-related knowledge, and a familiarity with business and financial matters*' (2). Further, Carroll (1979) – in one of his most impactful papers – defined the Social Responsibility of any organisation and its executives to span (in order of importance); Economic responsibilities, Legal responsibilities, Ethical responsibilities, and Discretionary responsibilities. Whilst we feel that Ethical and Discretionary responsibilities to society are sufficiently captured by Character, a sufficient understanding of Economic and Legal aspects of business are crucial for organisational and business leaders. Further, the Engineering Council (2016) state that individuals with Incorporated Engineer status (and above) should have an appreciation for '*legal and statutory requirements*' and take into account '*the need to progress … economic outcomes*' (46). Considering these points, we would subdivide Business Knowledge into Accounting and Finance, Business Strategies, Economics, Law, Marketing. However, based on a persisting change in the landscape of the engineering industry, we propose the further inclusion of Entrepreneurship, as suggested by (Whetten and Cameron, 2011). The post-industrial world has seen a decline in engineer employment from large industrials, with a rising number of graduates assuming positions in alternative, more entrepreneurial routes such as self-employment, Small and Medium-sized Enterprises (SMEs), and start-ups (Wei (2005), Galloway et al (2005), Nabi, Holden and Walmsley (2006)). If this trend continues, the engineering leaders of tomorrow will likely require more and more entrepreneurial prowess. Naturally our leadership education should also reflect this change, and thus it will be a consideration.

Interpersonal skills are widely regarded as vital for any leader, irrespective of their field or profession. Many scholars go as far as defining leadership as an interpersonal phenomenon (Bass and Bass, 2009); there is little scholarly doubt of its importance and it should be included. We propose interpersonal skills required for leadership be subdivided into Communication skills (Koontz and O'Donnell (1955), Bass and Bass (2009), Barge and Hirokawa (1989), Yukl (2010)), Influencing others (Barnard (1956), Koontz and O'Donnell (1955), Yukl (2010)), Peer evaluation (Supporting peer/subordinate Continual Professional Development (CPD) (Engineering Council, 2016)), Teamwork (Sosik and Dionne (1997), Boyatzis (2008), Yukl (2010)). We also propose the further sub-division of Communication skills into Oral Communication, Written Communication, Displaying Data (communicating data effectively) and Explanatory Skills (the ability to articulate complex ideas to an audience).

Intrapersonal skills encompass the cognitive abilities within oneself utilised to analyse, rationalise, and process problems or stimuli along with the creation of new ideas. Whether acquired or inherited, Mumford et al (2017) found that the literature on the topic '*indicates that certain cognitive skills are a critical determinant of leader performance'* (1). Thus, we propose the subdivision of such intrapersonal skills of an engineering leader to span Analysis Skills (Mumford et al (2017), Whetten and Cameron (2011)), Innovation (Mumford et al (2017), Yukl (2010), Whetten and Cameron (2011)), Problem-Solving Skills (Mumford et al (2002), Mumford et al (2017), Whetten and Cameron (2011)), Self-Evaluation (Boyatzis (2008), Engineering Council, (2016)).

Whilst many scholars define management and leadership to be distinct and separate (Bass and Bass, 2009), some claim we are observing an intertwining of the roles – with '*such distinctions between leadership and management … neither accurate nor useful*' (Whetten and Cameron, 2011, 34). From a practical sense however, the importance of such skills and knowledge bases increases for engineers assuming leadership roles (Farr, Walesh and Forsythe, 1997). Therefore, in order to maintain the stance of pragmatism, it should be considered. We propose management pertinent to Engineering Leadership to span 5 bases – Change management (Yukl and Lepsinger, 2004), Project Management (Engineering Council, 2016), Resource Management (Yukl and Lepsinger (2004), Engineering Council (2016)), Time Management (Adair (1984), Whetten and Cameron (2011), Engineering Council (2016)), Risk Management (Burke and Barron (2014), Engineering Council (2016)). It must be noted, in this context, management is not necessarily synonymous with aversion or minimisation, rather the overarching mastering of the area (e.g Risk, Change) – be that minimisation or utilisation.

Research gaps

Some scholars have adopted the stance that leadership education should be a solely intrapersonal pursuit (Barling, Weber and Kelloway (1996), Neck and Manz (1996)). Others believe it to be an isolated phenomenon and should thus be developed independently of other skills. However, such a stance would disregard the suggestions by opposing scholars and many in industries – that leadership is naturally intertwined with skills such as management, business acumen, entrepreneurship, innovation, and ethics. Some approaches in HE do tend to blend leadership along with other skills that allow for its application into various project settings. This aims to develop a more comprehensive training environment, whereby students learn the theory and have the ability to apply it within a structured programme. It must be noted that integrating specialised independent modules for the development of leadership might be a challenge for some programmes due to their already stretched syllabus. Further, how can we expect undergraduates to study specialised and intensive leadership modules without the ability to apply it to a real-world situation? In this context, some researchers have even questioned whether leadership can be effectively taught in an academic environment at all (Elmuti, Minnis and Abebe, 2005). From the literature review, it is abundantly clear that there is still a lack of consensus over how we define and develop leadership within individuals. The theories behind leadership development are debated almost as much as leadership itself. For this study, we have derived the key elements for defining Engineering Leadership in HE. Employing this leadership framework removes a degree of researcher bias by explicitly predefining the hierarchy of themes which will be later referenced in the analysis.

It is clear that leadership is one of the most widely demanded skills in the STEM industry; hence, more investigation needs to be carried out into this area of engineering pedagogy. Although there is little to no consensus on what approach should be taken by those in academia, completely removing leadership and management education from the curriculum will not contribute to bridging the skills gap. It is clear that the idea of integrating leadership development seamlessly with existing course content needs to be examined more deeply, and the outcome of such integration needs to be assessed. The prime objective of this paper is to contribute to such a discussion. By utilising content analysis, it will critically evaluate the current state of BEng leadership education in the disciplines of electronic engineering within the Russell Group UK universities and will compare and contrast with the current needs of the STEM industry. This will be followed by a case study of approaches used by the Department of Electronics at the University of York and interviews with academics.

Research methodology

This research carried out thematic content analysis of module specifications and publicly available descriptors of engineering courses published by UK Russell Group universities. In order to present a reliable and coherent analysis, the researchers focused on one specific field of engineering – Electronic Engineering. The goal of this study was not to fully capture and categorise every field of engineering; such an approach would be an extremely monumental and ambitious objective for two researchers. Rather, this study sought to build a deeper understanding on how leadership is integrated in engineering curricula by exploring one specific field as an example. Also, the association and expertise of the two researchers with Electronic Engineering added a level of familiarity to the subject content. The population selected for this phase of research, as outlined in the project aims, were Russell Group universities offering BEng Electronic Engineering courses. The justification for selecting these universities was that it was both possible and feasible to gather data for all Russell Group institutions offering these courses, resulting in the group being represented in its entirety.

By limiting the sample set to Russell Group universities, the assumption was that their BEng Electronic Engineering courses would be some of the best within the UK in terms of quality and consistency of teaching and research. Such an approach also meant researcher bias in the selection of institutions was removed and thus the possibility of a random sample not being representative of the whole population removed too. Many departments offer multiple variations of the Electronic Engineering stream, but only the core BEng Electronic Engineering stream was selected for each university, along with any compulsory or optional modules taken along that particular stream. The justification for selecting this stream alone is that it is a suitable basis point for analysis. The majority of students will roughly follow this core pathway and it is the most representative of the course content at a given institution. Apart from that, many universities offer alternative streams which vary significantly between institutions. This would, therefore, lead to a flawed study if such varied courses were compared directly.

Content analysis is well founded and has been utilised in various areas within the social sciences for decades. However, its use in analysing academic courses has been limited. There has been utilisation of the method for analysing entrepreneurial content (Malekipour et al, 2017), environmental content (Chakraborty, Singh and Roy, 2018), development of teamwork competencies (Zydziunaite, 2004), and rating the effectiveness of online courses (Sonwalkar, 2002). It has yet to be utilised for analysing the integration of leadership competencies within HE. The rationale behind utilising this method was that it had potential to provide a new approach to more objectively evaluate the extent of leadership integration in BEng Electronic Engineering courses. Carrying out such analysis contributes to filling a gap in the literature surrounding leadership education in disciplines of engineering, whilst simultaneously investigating the effectiveness of content analysis methods for evaluating both explicit and implicit course content. In order to carry out the content analysis, each Russell Group university was accessed, and all module specifications for BEng Electronic Engineering courses downloaded for offline access. NVivo 12 – a qualitative data analysis software – was used for content analysis. NVivo allows the user to highlight and mark references to specific nodes (or themes) present in the text; facilitating fast content analysis of the data compared to a manual approach. It also provides features for effective categorisation and cross comparison of processed data, along with the ability to export data to suitable data analysis software suites such as Excel or MATLAB. The hierarchy of nodes and sub-nodes utilised in NVivo were the same as the elements of leadership outlined earlier (Table 1). Each module specification was examined and any direct – or sufficiently close, but indirect – reference to one of these elements linked to its corresponding node in NVivo. As written language is an interpretive medium, if one were to solely consider direct word-for-word references to the elements of leadership outlined, then this would likely lead to a weaker and less representative set of results which poorly detect the intended meaning of the text. Therefore, indirect and implied references to the elements of leadership were also considered; only where it was clear and obvious that the implied meaning was sufficiently synonymous to one of the nodes outlined in the elements of leadership. In the interest of consistency, this interpretation was conducted by an individual researcher.

Once completed, the themes present in each module were investigated and analysed using quantitative methods and supplementary logical analysis. Therefore, whilst the data is qualitative in its origin, the analysis is quantitative in its approach. The use of content analysis in this context is dependent on some assumptions. These assumptions, whilst not necessarily affecting the accuracy or importance of results, must be considered and critiqued in the interest of clarity and to prevent misinterpretation of the results. The core assumption is that if universities intend to include elements of leadership and/or management into their modules, then it will be discussed or mentioned within their module specifications. Before proposing to carry out the research in this manner, a number of BEng Electronic Engineering module specifications were sampled for the quality of descriptive content contained within. Following the pilot, other modules were included in the sample and the set was deemed to contain sufficient qualitative data in order to conduct meaningful content analysis. It was also assumed that the content of the selected module specifications for the universities at the time of data collection were up-to-date, factually correct, and not substantially embellished. Furthermore, as previously discussed, due to the course specifications being descriptive, there is a strong element of human influence in how the specifications are written and interpreted. By utilising only one individual for the interpretation and processing of results, this minimises discrepancies in the interpretation process. However, there will still be differences in the language utilised in the module specifications. That will naturally introduce unavoidable discrepancies between equivalent modules; even though this is expected with content analysis, its influence needs to be considered when interpreting results.

For the case study of the University of York, interviews were conducted with three academics within the department of Electronic Engineering who are actively involved with engineering leadership and management courses. One of the academics – Participant 1 has been leading the business management stream for over 25 years. Prior to this teaching role, he had 18 years of industry experience working in roles such as design engineer, technical manager and programme manager. For the second academic Participant 2, following a successful 30 years of extensive experience in one of the top telecommunication companies in the UK, the teaching role at York utilises his expertise in areas like strategic leadership and project management. The final academic Participant 3 in this study has over 30 years of teaching and research experience within the department leading several large-scale research projects over the years. The three academics interviewed in this study are White British. The interviews conducted were semi-structured and audio-recorded. The semi-structured approach allowed the interviewer some flexibility to explore deeply any areas that emerged during the interviews which were deemed highly relevant or appropriate to the line of research. The interview explored themes such as the academics' knowledge and understanding of leadership and its importance in industry, their opinions on the importance of leadership in education. Some of the questions include:

- How would you best describe leadership?
- To what extent do you think graduate leadership qualities are desired by industry?
- What do you think is the best way to encourage leadership development among undergraduates?
- Can you think of any specific module(s) here at York that you feel develop leadership competencies the most among undergraduates?

Each interview lasted approximately 30–45 min. Following the interviews, textual transcripts were drafted and then uploaded into NVivo. Using thematic coding approach, different themes were identified from the transcripts and then coded in NVivo. This process led to a series of prominent categories which are used as a basis for discussion in this paper.

Analysis

Of the 24 Russel Group universities, there were four universities which did not offer a BEng Electronic Engineering course (or equivalent). These were the University of Oxford, London School of Economics, University of Cambridge, and Durham University. Further to this, The University of Birmingham did not have publicly available module specifications and did not supply any. Therefore 19 of the 24 institutions were included in the study, with a total of 635 module specifications analysed. The total population of Russell Group institutions offering a BEng Electronic Engineering course was therefore, represented in its entirety (less one institution that could not be included), this, therefore, makes statistical analysis to evaluate the significance or certainty of data redundant. Because the data was qualitative in its origin, such evaluation of the significance could be made through critical analysis.

Since this study only concerned BEng streams, modules exclusive to MEng[3] streams were not within the bounds of this research. Further, University of Glasgow and the University of Edinburgh follow a standard Scottish four-year course structure, significantly different to the standard BEng structure in the rest of the UK (England, Wales and Northern Ireland). The extra year at these institutions amounts to 120 extra credits, and comparing a 360-credit course to a 480-credit course would be inappropriate. It is the completion of the fourth year of an engineering degree in Scotland that satisfies the education for an Incorporated Engineer, resulting in a BEng Honours award; equivalent to that of England, Wales and Northern Ireland. The Scottish education system permits students to enter university with Scottish Highers, which is equivalent to AS levels. Further, it allows high performing students taking Scottish Advanced Highers or A-Levels to take a 360 credit BEng degree by skipping the first year. It is this route which shall be considered. Therefore, it was decided to omit from consideration the Scottish first year, as it is of similar content level to a Foundation Year in England, Wales and Northern Ireland.

Most referenced elements

When summing all the references to each individual skill or element outlined in Table 1, the results in Figure 1 were obtained. The problem with Figure 1 however, is that it does not consider the fact that

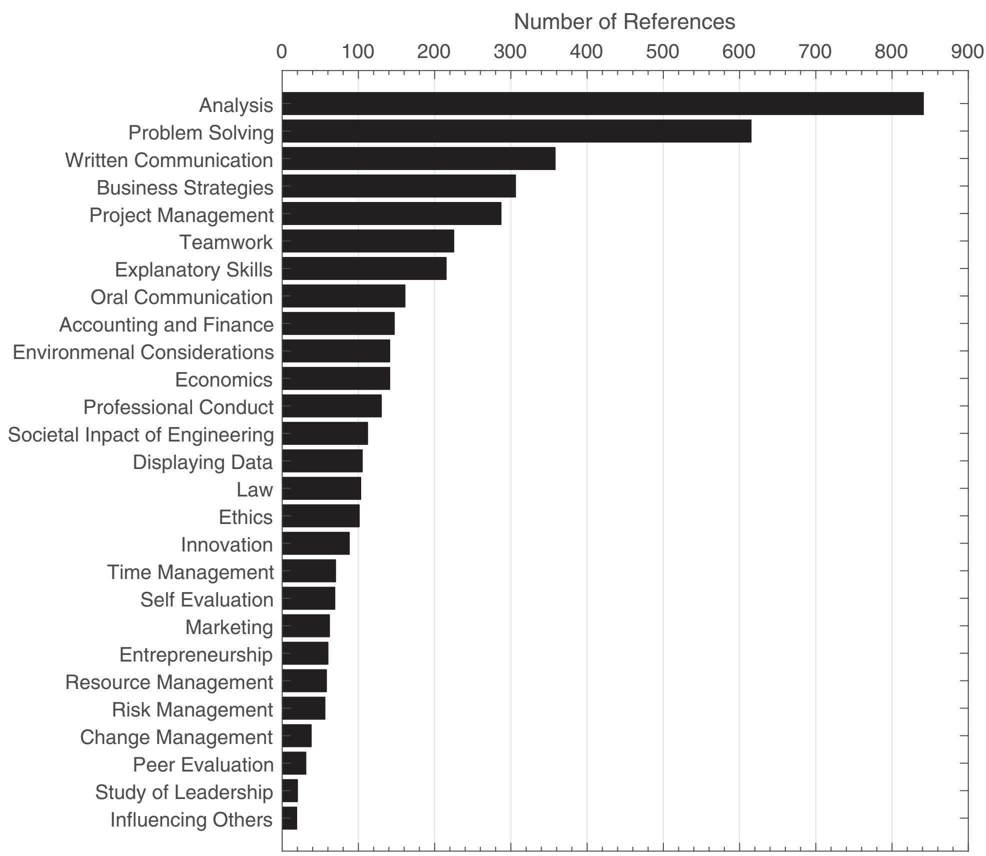

Figure 1. Total references to each leadership element.

an individual skill may be referenced multiple times per module; this can slightly inflate the reference count of some elements. Figure 2 was created in order to remove this problem by displaying the percentage of modules which reference each individual element at least once.

Observing the two graphs, there are six elements which are present in the upper quartile of both Figures 1 and 2, these are:

- Analysis skills
- Problem solving skills
- Written communication skills
- Explanatory skills
- Teamwork
- Project management

This indicates that these skills associated with leadership are utilised the most in BEng Electronic Engineering courses. Analysis skills and problem-solving skills are referenced the most; 757 and 562 times respectively. When considering the nature of an engineering degree, this is expected. Engineering draws heavily on these skills, and therefore it is of no surprise that the reference count reflects this. Such a result implies that graduates will have had the most exposure to these elements, or at least required to use them the most. If a leadership role demands the use of these skills, they should have had more exposure to utilising such skills relative to the other elements sampled for.

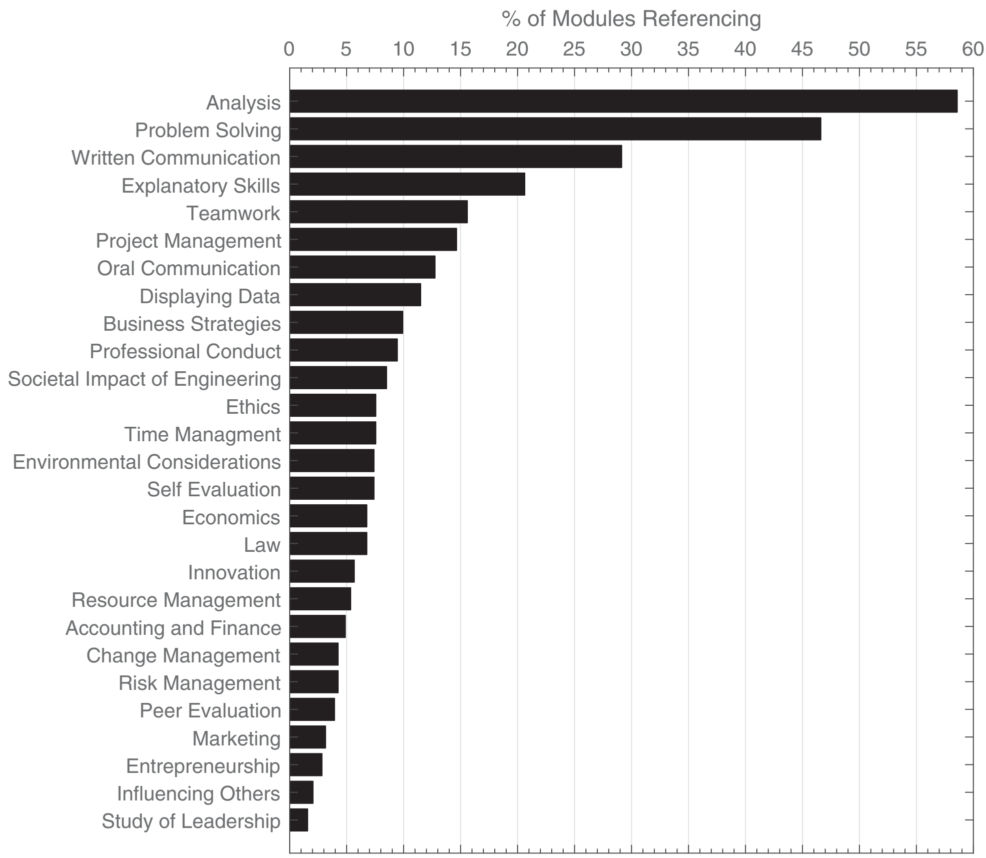

Figure 2. Percentage of modules referencing each leadership element.

Written communication skills and explanatory skills are also present in both graphs. The reason these skills have such a high reference count is likely due to them being critical methods of assessment within university modules. Undergraduates are required to attend a written exam or submit a written report for the majority of their modules, and this will require an element of explanatory skills. Therefore, the number of references for each of these are naturally linked, as the two skills are commonly utilised in unison. The presence of teamwork and project management is noteworthy. As established in the literature review, these two skills are widely regarded as crucial for an engineering leader. However, they are not necessarily the skills which those in industry have outlined that graduates are deficient in. Project management skills are crucial for technicians, engineers and engineering leaders alike. Therefore, the inclusion of them into an engineering degree is critical (included in Engineering Council's UK-SPEC (Engineering Council, 2016)), with or without consideration for the development of leadership competencies. Likewise, teamwork is critical for the modern STEM workplace. It can thus be inferred from such results that graduates of Electronic Engineering degrees will, on average, have been required to utilise such skills throughout their degree and could be better equipped in these areas relative to others. This indicates a good level of integration of these skills into the courses sampled.

Least referenced elements

When observing the two sets of data, it is apparent that there are elements in the lower quartile of both Figures 1 and 2 are the same, albeit ordered slightly differently. These are:

- Study of leadership
- Influencing others
- Entrepreneurship
- Marketing
- Risk management
- Change management
- Peer evaluation

Therefore, since these elements are the least referenced, and also referenced in the fewest number of modules, it would suggest they are integrated the least into the BEng Electronic Engineering degrees sampled. Now, four of these – Entrepreneurship, Marketing, Risk Management, and Change Management – were previously discussed as either being essential leadership elements for engineering managers, or found to be deficient in industry by bodies such as the IEEE. Further, these four elements may indeed be easier to integrate alongside existing imperatives for many of the courses sampled – especially when compared to somewhat more sizable and detached subjects such as Law, Study of Leadership, or Accounting and Finance. They are hard-skills and can thus be taught in an academic environment. However, they also have sufficient crossover and relevance to engineering projects, so as not to impede the education of engineering itself if integrated.

Peer-evaluation is also a skill appears to be least referenced, yet it was previously established as a key skill for both effective leadership and CPD. Around 5% of BEng modules of Russell Group universities incorporate elements of peer evaluation, clearly showing a lack of roll-out of this element to BEng courses. Despite this, peer evaluation has been outlined by the RAE and Engineering Council as a critical skill for engineers (Engineering Council, 2016); understanding the development needs of colleagues and supporting their CPD as well as your own. The fact that only 5% of modules reference peer evaluation is somewhat surprising when over 15% of modules reference teamwork. Further, only 3.5% of modules analysed reference both teamwork and peer evaluation. Hence, there appears to be a disconnect between the utilisation of peer evaluation and teamwork – only 20% of all modules referencing teamwork simultaneously reference peer evaluation. The origin of such a discrepancy probably arises from several causes: the level of teamwork integrated into many modules may not be substantial or prolonged enough to justify peer evaluation; teamwork may be regular but with different peer groups; or module designers may fail explicitly to outline the integration of peer evaluation alongside teamwork. Modules may also contain elements of peer evaluation without teamwork, a common occurrence in individual projects which are presented before, and scrutinised by, others – and vice-versa.

As somewhat expected, the study of leadership occurs the least. This is likely due to lack engagement by course designers with the need to bridge the leadership skills gap, an inability to integrate leadership with existing modules, or an inability to offer leadership as a standalone module due to an already stretched syllabus.

The list of least referenced elements, whilst not being definitive, does give a useful indication of which leadership elements are deficient within BEng Electronic Engineering Degrees at the Russell Group universities sampled, and thus, which should be considered for further integration into BEng Electronic Engineering courses in the future. It agrees with the sentiment of many in industry, and this gives a strong indication that these are areas that can be improved.

At this point, one may put forth the argument that, if leadership is the least referenced element, encouraging universities to offer a standalone compulsory module for leadership development would be an appropriate solution. Advocating such an approach would significantly simplify the complexity of the solution to bridging the leadership gap. Whilst the authors do not in principle disagree with this stance, practical limitations mean such a recommendation is optimistic. In order to meet accreditation standards set by bodies such as the IET, engineering course designers in the UK are required to prove they cover a sufficiently broad and deep set of technical and non-technical skills. Though the extent to which each area is developed needs to be rigidised, one cannot have discrepancies between accredited institutions with respect to the weighting of technical and non-technical teaching hours. With this in mind, the IET state that, at most, 30% of all course credits should be non-technical (IET, 2020). This prioritises exposure to technical components, and ensures non-technical work is still encouraged, but limited. Hence, there is an upper bound upon the extent to which standalone supplementary modules can be integrated. Course designers must, therefore, select some non-technical modules over others – and many have existing modules in place. Whilst leadership development is important, and a dedicated module would likely aid development in this area, one may put forward an equivalently strong argument for the integration of a range of other non-technical domains. This, therefore, emphasises the importance of a thorough consideration of implicit integration of the Elements of Engineering Leadership, rather than leadership itself.

Compulsory/Optional dominance

The content analysis also allowed for a new method of establishing the extent to which leadership skills are integrated in either compulsory or optional modules, giving an indication of the delivery method utilised by universities. Further, if the Elements of Engineering Leadership were referenced significantly more in optional modules, this would suggest an increased likelihood that an undergraduate can fail to have sufficient exposure to such elements, because they can opt-out.

Upon studying Figures 3 and 4, it would appear that branches of leadership associated with character development are taught almost equally as much in the average optional module and average compulsory module – indicating a somewhat equal utilisation in both optional and compulsory modules. To a similar degree, the same can be said of the study of leadership itself.

However, it would appear that for Interpersonal Skills, Intrapersonal Skills and Management Skills, compulsory modules have a higher average reference count, and also a higher number of modules referencing them at least once. A result which indicates good integration of these skill areas into the average compulsory module compared to the average optional module, and likely a blending of these skills with the core engineering curriculum.

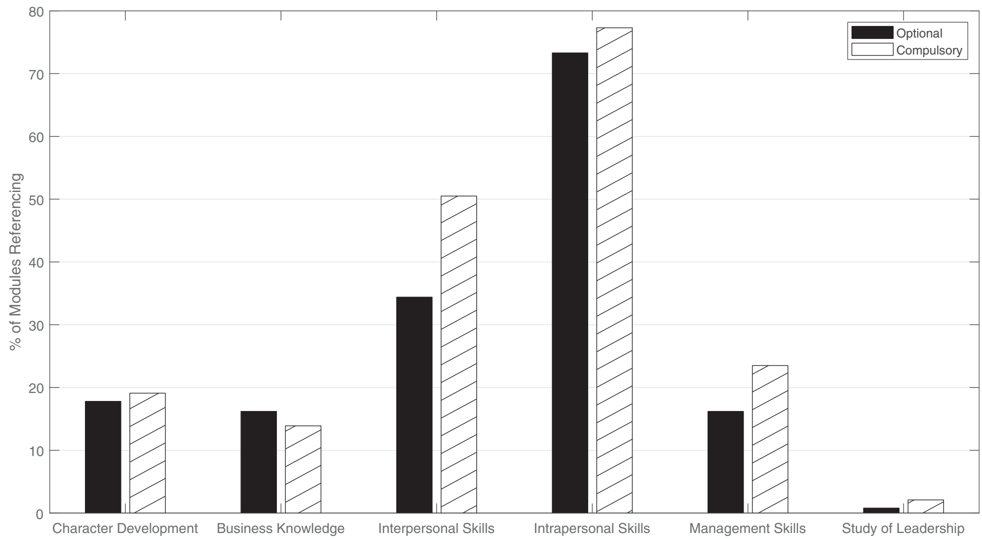

Figure 3. Percentage of modules referencing each skill type.

On the other hand, the average number of references to the development of Business Knowledge is greater in optional modules than compulsory modules, despite having almost the same number of modules referencing it at least once. This indicates the common delivery approach for business related skills is likely through specialised optional modules, each with a high reference count to business related skills. Whilst a discussion on the effectiveness of such an approach is outside of the bounds of this paper, the delivery of this skill type is likely different to the other leadership skill types. Results indicate the business skills have been integrated well into the optional module structure, however, relative to this, a marginally lower level of integration into the compulsory module structure.

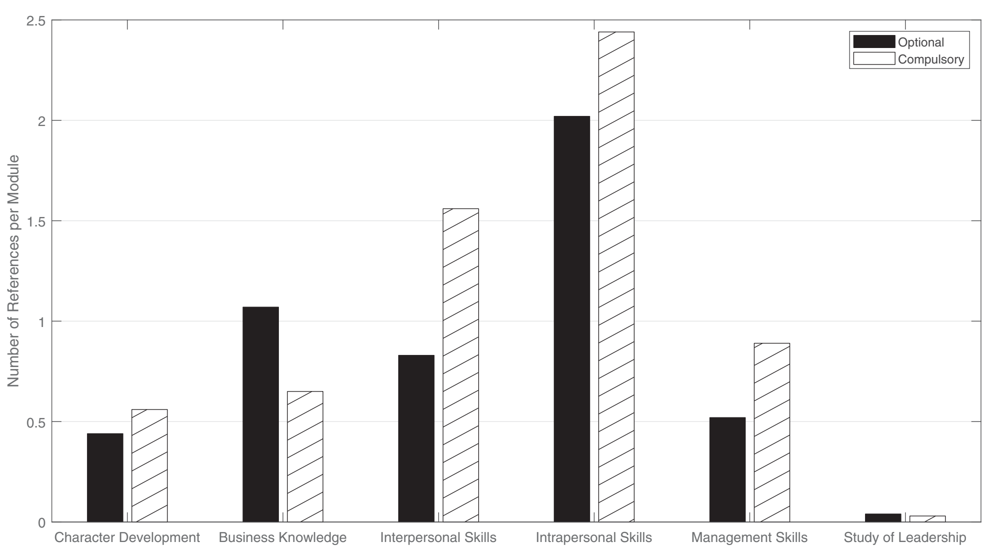

Figure 4. Average reference count per module for each skill type.

Development across academic years

Content analysis provided means of analysing the change in leadership skill usage throughout the undergraduate programmes sampled. By grouping leadership into the six core areas, as outlined in Table 1, and measuring the average reference count per module across the academic years, this showed some interesting trends (Figures 5 and 6). As the academic years progress, it would appear that interpersonal skills and intrapersonal skills exhibit a decrease in average reference count and percentage of modules referencing them. Whilst business skills and management skills experience a slightly upward trend over the years. This trend indicates that at the beginning of the courses sampled, there is a greater importance attributed to the development of soft leadership skills such as intrapersonal skills and interpersonal skills, whilst as the courses progress, there is a rise in the education of hard leadership skills such as business and management.

Upon studying the course structures, the explanation behind this seems to be that course designers consciously integrate soft skills into the compulsory first year modules, affording students little opportunity to opt-out. Whereas in final years, undergraduates are commonly afforded the choice of modules in varied academic disciplines; diversifying their academic base beyond engineering alone. These fields of choice are commonly business and management orientated, however there are a broad range, most with application in the STEM sector.

Module comprehensiveness

One constructive usage of the content analysis was in the development of a comprehensiveness ranking, or index. By utilising the Elements of Engineering Leadership introduced in Table 1, this allowed the ranking of engineering leadership content based on a reductionist approach. Evaluating leadership content present in modules from its core elements, rather than the overarching definition of leadership itself. This form of analysis facilitates a more objective approach in comparing the breadth and depth of leadership integration between modules, allowing for a quantitative approach to be utilised in the comparison rather than a solely qualitative. Such an approach should provide a suitable data-point for further discussion on what module types are the most comprehensive in their leadership integration, based on the framework outlined in Table 1.

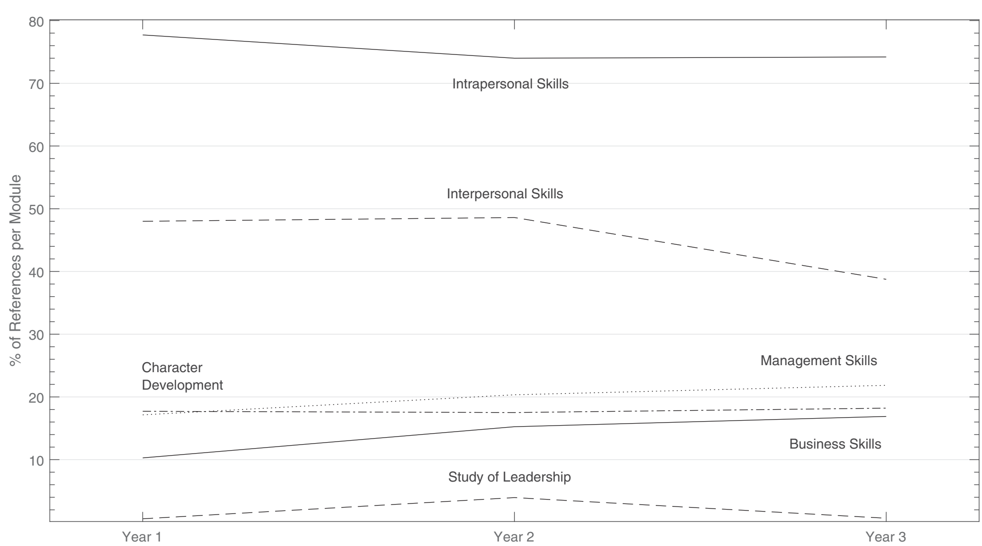

Figure 5. Development of percentage of modules referencing each skill type.

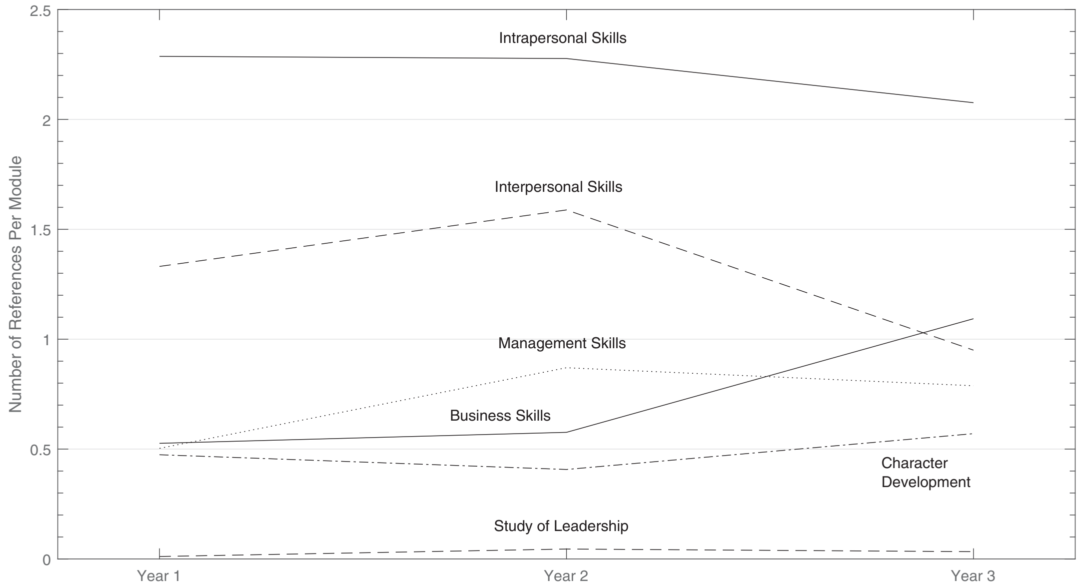

Figure 6. Development of average reference count per module to each skill type.

Table 2. Most Comprehensive Modules.

	Module Name	Code	Institution	Coverage	C_V
1	Engineering Entrepreneurial Skills	5CCS2EES	Kings College London	22	0.47
2	Project and Professional Issues	EEE208	Newcastle University	22	1.34
3	Professional Engineering	CENG2008	University of Bristol	19	0.62
4	Engineering Project Management	EN3024	Cardiff University	19	0.73
5	Engineering Design	ELE00027C	University of York	17	0.87
6	Professional Engineering and Innovation	ELE2036	Queens University Belfast	16	0.53
7	Entrepreneurial Skills Development 1	EMC1111	University of Exeter	16	0.60
8	Individual Project	EN3400	Cardiff University	16	0.62
9	Professional Studies	ELEC3030	University of Leeds	16	0.80
10	Entrepreneurship Online	BS0852	Imperial College London	16	1.24

In order to fairly compare modules, they were first sorted according to their coverage of all 27 Elements of Engineering Leadership, then they were further ranked according to a normalized measure of dispersion across all the elements. In other words, the coefficient of variation (C_V). Given an array of reference count data $\boldsymbol{\psi}:=[x_0, x_1, \ldots, x_n]$, where $n \in \mathbb{N}$ denotes the number of separate leadership elements or categories sampled for. Further, let us define the corresponding arithmetic mean as $\mu_{\boldsymbol{\psi}}$, and population standard deviation as $\sigma_{\boldsymbol{\psi}}$. The coefficient of variation can be defined as such

$$C_v(\boldsymbol{\psi}) := \frac{\sigma_{\boldsymbol{\psi}}}{\mu_{\boldsymbol{\psi}}}. \tag{1}$$

For example, let us consider a module with the following reference count data across six leadership categories, $\boldsymbol{\psi} = [10, 12, 7, 15, 3, 4]$, clearly $\mu_{\boldsymbol{\psi}} = 8.5$, $\sigma_{\boldsymbol{\psi}} \cong 4.27$. Therefore, applying Equation (1),

$$C_v(\boldsymbol{\psi}) \cong 0.5$$

The rationale behind utilising this metric being that the lower the module's coefficient of variation, the lower the degree of dispersion with respect to its mean, therefore implying a greater likelihood that all elements are of equal importance to the nature of the module.

Table 2 outlines the top ten modules according to the comprehensiveness analysis. The results show a clear trend in the nature of the most comprehensive modules based on the framework in Table 1. That is, that they generally utilise engineering skills with a supplementary field (e.g Business, Management) within a team-project based environment. Of course, these results are indicative only and not to suggest that such modules are the most effective in leadership development, rather that they appear to reference – and likely utilise – the broadest range of leadership skills.

The data also identifies a crucial flaw with the utilisation of content analysis. The 'Individual Project' offered by Cardiff University appeared to perform well in this ranking, however since the majority of final year projects are wholly the same across institutions, it would be logical to expect to see other equivalent modules performing equally as well. Alas, this is where the practical bounds of content analysis become apparent. The creative freedom afforded to those who write module descriptors can artificially inflate or deflate its apparent qualities when compared to almost identical modules.

Case study: University of York

The Department of Electronic Engineering in the University of York first established in 1978 offers a range of IET accredited BEng and MEng Electronic Engineering courses. Due to subject specific research specialisations, this department offers a range of routes for undergraduate studies including Communication Engineering, Computer Engineering, Nanotechnology, and Business Management. As one of the Russell Group universities, York has maintained a good reputation in teaching and research. The Department of Electronic Engineering was ranked first for teaching and second for overall student satisfaction in the Russell Group according to the 2018 National Student Survey (NSS)[4] (NSS, 2018).

Since 2016, the University of York BEng Electronic Engineering course has operated on a fixed module structure up until the third academic year; students are then offered three optional modules in order to gain further knowledge in more specialised fields. The new course structure is outlined in Figure 7 and this framework was primarily used for this study's analysis. Undergraduates are required to complete compulsory modules until year three, in which they can specialise in the optional module areas. As established in the literature review, the STEM landscape is demanding a greater importance be attributed to leadership skills throughout the HE system. The Department of Electronic Engineering at York has therefore adopted an integrated approach, along with a Professional Development Framework to facilitate leadership skills in their module structure and programmes. As part of this study, three academics having significant involvement in the education of engineering management within the department were interviewed; an intentional selection as they have a wealth of experience and knowledge in the areas of engineering leadership.

Year 1	Year 2	Year 3	
Engineering Design (ELE00027C)	Design, Construction & Test (ELE00040I)	BEng Individual Project (ELE00004H)	Digital Communication Systems (ELE00050H)
Analogue Electronics & Physics (ELE00023C)	Java Programming (ELE00041I)	Control (ELE00049H)	LAN & Internet Protocols (ELE00052H)
Mathematics (ELE00030C)	Engineering Mathematics, Signals & Systems (ELE00031I)	Communication Systems (ELE00048H)	Mobile Communications Systems (ELE00012H)
Digital Circuits (ELE00025C)	Noise, Waves & Fields (ELE00034I)	Applications of EM (ELE00046H)	Cloud & Distributed Computer Systems (ELE00047H)
Introduction to Programming (ELE00029C)	Semiconductor Devices & Circuits (ELE00035I)	Principles of DSP (ELE00055H)	Digital Engineering (ELE00011H)
Digital Systems (ELE00026C)	Algorithms & Numerical Methods (ELE00028I)	Analogue Engineering (ELE00045H)	Accounting & Finance (ELE00015H)
	Digital Design with HDL (ELE00030I)	State Space & Digital Control (ELE00057H)	Nanoelectronics (ELE00023H)
			Photonics & Nanophotonics (ELE00025H)

Compulsory

Optional - Select 3

Figure 7. BEng Electronic Engineering Structure (University of York).

Industry and employability skills

Each academic interviewed for this study echoed similar sentiments about the skills gap that was highlighted in the recent IET skills survey (IET skills survey, 2019), Participant 2 stated '*They [industry] feel soft skills are grossly missing in typical graduates … When we talk to industry –– they would give us this huge list of [soft] competencies that they wanted us to develop among our students*'. The focus of HE in the engineering discipline should, therefore, be oriented towards addressing these skills shortage so as to create more 'work ready' engineering graduates. There is a need for educators to first understand these skills and then design curricula and teaching approaches that align with the needs of the industry. In this context, Participant 1 explained '*As a department, we are extremely experimental in what we do … We are constantly looking for opportunities to be creative*'. As Barišić and Prović (2014) note, there is now a need for transformation of teaching approaches and educational methods.

Participant 1 stressed the progressive nature that universities have adopted over the years adding '*People went to universities to read for a degree, and nothing else. These days we place more emphasis on employability skills*'. Participant 3 agreed, stating that '*there's a big move in engineering education to do much more of this*'. These views confirm that engineering courses in recent years have become far more pragmatic in their approach to developing employability skills, due to increased external pressures and a willingness from academics to modify their approach. Pressure such as that from engineering accreditation bodies like the IET, who increasingly place more importance on developing a well-rounded engineer rather than solely a technically competent one. Therefore, there is an emphasis on creating a learning and development environment in HE where students are given opportunities to build upon their overall employability skills. In this context, Participant 2 explained,

> York has made a conscious effort to integrate the skills. More and more universities are starting to embed leadership and management skills due to pressure from accreditation bodies such as the IET, with each accreditation increasing the importance of leadership development. Universities should be more proactive in preparing for changes needed in pedagogy.

The academics stated that engineering degrees are, on the whole, better than their subject counter-parts; they see the importance. Yet that is not to suggest there is no room for further development in this area. The academics interviewed supplemented this with the suggestion that course designers need to express leadership themselves by 'being ahead of the curve'; implementing further change to develop soft skills such as leadership competencies, beyond that needed for accreditation alone. Participant 1 who led one of the most popular course streams within the department – stressed the need for academics to have leadership skills, explaining

> They do need leadership and they need to be proactive … There's no point in being reactive and waiting … When you have to be reactive, be reactive … Most of the time you try and avoid having to react. That's leadership … As the group leader for one of the streams, I am very keen on experiments and testing to see what's actually effective.

In the context of the department, this academic further added '*The leadership in the department about what is coming and how to prepare for it is excellent*'.

Integrated approach towards leadership development

Today's students according to Williams (2011), '*tend to be experiential learners – they prefer to learn by doing, as opposed to learning by listening*'. The Electronic Engineering department at York has therefore placed a strong emphasis on active learning which is key for developing soft and hard leadership competencies alike. They have adopted an integrated approach where management skills and soft skills such as leadership and teamwork are integrated in to modules throughout the degree course. There is no dedicated module on leadership for BEng students under their compulsory module structure but, for MEng students, there is an optional module called 'Skills for Business

Leadership' in their final year. This is the only specific module on leadership, '*This module explores the concept of leadership and the various skills associated with a leadership-oriented role within an organizational setting. It will look at decision-making and problem-solving techniques as a leader and how to manage projects and facilitate employee skills*' (University of York, 2020a).

In the overall undergraduate programme structure, there seems to be a strong emphasis on project-based learning which can give students an opportunity to learn the various aspects of leadership, collaboration, peer assessment, problem solving and decision making. For engineering students, this process is absolutely vital to build critical thinking. As Thorpe (2004) explains, '*Students employ critical-thinking skills to explore complex concepts central to their discipline. When students systematically engage in critical thinking, they tend to develop insights not only into the concepts but also the learning process as well*'. But, as evident from this department at York, the facilitation of leadership theory and application among students might need a carefully planned approach. As Participant 1 explained

> In stage 1, it is very early. I think they are exploring leadership at that stage. That would be a good point to develop theory, then they can see it working or not working, and they can see the stages of team development. I think there is a good opportunity to put the theory in early years, but the application of it is more difficult. I think it should involve group work. Otherwise it's contrived and theoretical.

Participant 3 similarly noted '*I don't think any of our first years, as a cohort, have any idea about leadership*'. As a lot of them come straight from school, their experiences with leadership tend to be limited. This is why York has carefully embedded project-based learning in year 1 and 2. The academics in the interviews observed

> Leadership really requires group activities … The new programme exposes undergraduates to team activities … The first two years are team-based, in the third year, BEng students carry out an individual project … Leadership is taught in an integrative approach … Now the new integrated masters that we will introduce in 2020, they will have group projects in all years.

Within the new structure, the compulsory Engineering Design (ELE00027C) and Design, Construction and Test (ELE00040I) modules implement the team-project based learning approaches throughout the first and second year. Each is an extended group project, with Engineering Design spanning the whole of year one and Design, Construction and Test being completed over the spring and summer terms of year two. The Programme Learning Outcomes (PLOs) for Stage 1 and Stage 2 explicitly include elements of teamwork, project management, business, law, ethics and interpersonal skills. A significant component of this is due to these two modules. When the academics were interviewed, they outlined that the Engineering Design module develops core soft engineering competencies throughout year one, whilst the Design, Construction and Test module takes these same competencies but develops them further into a more realistic project – increasing the academic and technical intensity. Both of these modules scored highly in the content analysis results, referencing 17 and 9 of the Elements of Engineering Leadership respectively. According to the content analysis results, the Engineering Design module appeared to be one of the most comprehensive modules on offer within the Russell Group universities. Participant 3 explains, '*For undergraduates, they need to see the relevance – and that's the challenge – no-one wants to come to abstract lectures*'. By utilizing such an approach, it allows students to draw upon and develop their interpersonal skills, engineering knowledge, management skills, professional conduct and entrepreneurialism. Some of these approaches have been brought in following previous experiences. On this aspect, one of academics stated '*We have tried in the past, and other departments have struggled as well – developing transferable skills – running lectures that no-one turns up to*'. Students, especially those in lower years, appear to lack connection with the lecture-driven, or theoretical approach to developing soft skills – and thus a significant portion of leadership competencies. The academics, therefore, outlined the importance of a situational approach to development. Placing students in positions in which they can perceive the relevance of utilising the skills learnt and have the opportunity to apply them directly. Participant 3 justifies,

> The utilization of skills in a situation is the most important way of learning … Elements of leadership should be taught alongside subjects which allow for its practical application, using an active learning approach … On our new courses that we're putting together, we're trying to build in the problem based approach [to developing leadership skills] – even more, from the first year.

During the interviews, one of the academic staff members stated that this problem-based/extended group project learning approach allowed for the utilisation of both hard and soft leadership competencies in unison. According to the academics, some of their students' module feedback show positive response towards this approach. When discussing why the 'Engineering Design' and 'Design, Construction and Test' modules were good for their development of constituent leadership competencies, they claimed it was not due to the teaching, rather the content, expectations and '*being thrown in the deep end*'. They stated that universities cannot teach soft skills, yet they can provide opportunities to develop them. Further, they can teach hard skills, but these also need to be supplemented with opportunities to apply them. Both of which, to some degree, are facilitated in years one and two of the new structure.

Leadership is a high- level construct and Participant 2 suggested *'Teach core skills, but make the application of them to a situation a key component of assessment. This ensures they can apply the skills'*. In this context, he outlined an example of a situation where they were required to assess public speaking - another high-level social phenomenon. Instead of assessing the act of speaking itself, they broke down the assessment into several simpler processes. The module assessed the student on the following:

- Research carried out on the topic
- Understanding of the topic
- Audience evaluation
- Designing a plan for the public speaking

Clearly, this approach was similar to that outlined in this research. It is reducing the high- level phenomenon to a number of examinable and comprehensible parts. Rather than testing the outcome, it ensures candidates have developed a formalised process to tackling a public speaking event they may take part in. Surely then, this approach can also be utilised in leadership development. Rather than teaching or assessing leadership itself, by utilising a reductionist approach – developing and testing surrounding skills or knowledge areas – this will give candidates the best chance to perform well as a leader. In much the same way, the public speaking component gave students the best chance at performing well as a public speaker, by developing the surrounding process, rather than the act itself.

York's professional development framework

It appears that the new course structure has led to the integration of key leadership competencies into the core modules, guaranteeing a degree of leadership development in each year of study. However, specialisation in areas critical to professional development has been attributed more to MEng students than BEng students. The justification for this is twofold: firstly, due to the extra academic years' worth of educational time, and secondly, due to it aligning more closely with their career trajectory. The MEng course satisfies the academic base for becoming a Chartered Engineer[5], and generally chartered engineers are more likely to progress into upper management positions – in which they will be required to exhibit the most leadership and management competencies present in the engineering sector (Farr, Walesh and Forsythe, 1997). Thus, it seems appropriate for them to be afforded the potential to expand in these areas – which the department's management team facilitate. Therefore, relative to MEng students, BEng students on the core Electronic Engineering stream are likely to be deficient in hard leadership competencies. However, it would be constructive to investigate if the level of exposure afforded to them is sufficient for industry, or whether they require more. According to the academics, from the yearly module feedback in the department, it appears that those students who took optional management modules felt they contributed to their development of hard leadership competencies and comprehension of leadership and management. Further, when asking academics which modules they felt developed leadership competencies the most, they listed many of the optional management modules, along with the 'Engineering Design' and 'Design, Construction and Test' modules. As noted earlier, it appears that some of the optional management modules do have a part to play in leadership competency development, especially in acquiring hard skills and knowledge in areas pertinent to engineering business. However, the general sentiment from academics is that the core BEng programme is already stretched and it is not necessarily feasible to integrate the range of management modules required to meet industry demand. Further, there is no guarantee that – if the management modules are offered – students will opt to take them. It provides no guarantee of exposure, outcome, or development. As one of the academics stated, leadership competency development requires an element of desire and self-motivation by students. Paul and Falls (2015) supported this view, stating that if students do not perceive themselves as leaders, they may opt out of such optional development – exacerbating the leadership skills gap. Considering this, and with an already stretched BEng syllabus, another approach is likely more feasible and effective in ensure leadership skill development. Rather than the introduction of additional modules in order to further leadership development, one which more seamless integrates with existing course imperatives. Employing such an approach, the department introduced a new scheme called the 'Professional Development Framework' in 2018.

The primary objective of the framework is to develop 'work-ready' engineering graduates and facilitate their personal effectiveness. Regarding the framework, the department states that it will provide students with opportunities to develop their personal and team-based effectiveness and progressively focus on preparing them for work once they graduate, '*We achieve this through a carefully planned programme of activities, starting with an intensive induction programme and continued throughout the academic year by masterclasses, workshops, intensive sessions and individual and group activities*' (University of York, 2020b). Participant 3 who took an active role in the development of this framework explains,

> The Professional Development Framework is the end-point of a 2-year discussion process with our External Advisory Board. Many of these Board members are industrial employers and had noted to us how (in general) engineering graduates are well-trained in the technology, but less so in managing their life, time and communications. In several rounds of capture, discussion and refinement, we drew up a syllabus of competencies that we wished all our graduates to have. On processing this through our teaching committee we realised that we needed a curriculum of professional development skills, some of which are experienced on the back of existing engineering assignments, and others that are taught and examined separately.

The department is currently in the process of introducing this framework to all its programmes and seems to be a proactive strategy to promote employability skills including leadership without being overly intrusive. Participant 1 conclude

> We want students to graduate from our programmes ready for the world of work, skilled not only in the technical aspects of their study programme but also in the generic or sometimes called transferable skills – those skills that stay with them for life and apply to any job or career they choose. In addition to skills, behaviours play a major part in success in life, behaviours are also a focus of our Professional Development Framework.

If soft skills such as core leadership competencies were contained in such frameworks, this could help formalise the inclusion of certain competencies into course content, where applicable. The introduction of this professional development framework seems to be a constructive step towards formalising the development of essential professional skills among students. By codifying a list of key areas that are critical to succeeding as a professional engineer, this would allow for module designers to reference them and see if any could be integrated in their modules. Whilst not developing leadership itself, it would make a progression towards promoting a more comprehensive education, one that develops competencies which are characteristic of leaders, or contribute to overall leadership competency. Further, such an educational approach allows for the combination of several leadership skills to be utilised in a single setting.

Conclusion

Today, the roles and responsibilities of twenty-first century engineers are constantly evolving and there is a need to understand the core skills and competences that organisations expect from modern engineers. Within an organisation, engineers are now expected to have a broad interdisciplinary knowledge, spanning areas such as intellectual property rights, data protection laws, ethics, compliance, and the impact of engineering towards a sustainable environment and economy. Researchers have concluded that engineers across sectors do have the potential to lead and there is now a need of a widespread recognition of engineering as a leadership profession. Engineering education has evolved over the years and there is also a growing demand for leadership development among engineering students and professional bodies such as the IET have strongly outlined the deficiency in skills such as leadership, management and communication among recent engineering graduates. For training twenty-first century engineers, universities should follow a more comprehensive teaching and learning approach with a focus on both technical and soft skills. This includes integrating leadership in engineering curricula. So far, the majority of the evidence of leadership integration in engineering curricula seems to be in the US rather than Europe. Some of the prominent examples include the Bernard M. Gordon- MIT Engineering Leadership Programme and the Engineering Leadership programme at the University of Texas at El Paso. However, there is limited literature or guidance available for UK academics on curriculum design in this context. Therefore, this suggests a need to review the implicit and explicit integration of leadership with engineering in UK HE courses.

This paper evaluates the current state of leadership education using a nation-wide sample of BEng Electronic Engineering course structures and contents of Russell Group universities in the UK. This is one of the first research studies to investigate the integration of leadership education in engineering courses in the UK. By utilising content analysis as a means of evaluating leadership development, this research demonstrates a new method of analysis and observation of the current state of leadership development in BEng Electronic Engineering courses.

One of the most notable points outlined being that some of the least referenced Elements of Engineering Leadership within BEng Electronic Engineering courses are also some of the most desired by industry. Such a finding reflects a disconnect between the leadership needs of industry and what undergraduate courses attribute the most importance to. Content analysis also provided another means of evaluating the extent to which certain areas on leadership are developed within either optional or compulsory modules. On the whole, the research appeared to show that there was a fairly equal spread between optional modules and compulsory modules; with slightly greater occurrence in compulsory modules. It also indicated that a lot of the business studies appeared to be utilised more heavily in optional modules. This finding is somewhat reassuring, as the courses are neither too rigid nor too fluid – it ensures both consistency of undergraduate exposure to leadership whilst allowing scope for further specialisation with optional modules. Further, it would appear that as the academic years develop, there appear to be consistent trends in what areas of leadership increase in reference count and what areas appear to reduce in reference count. More specifically a decrease in soft Intrapersonal skills and Interpersonal skills, with a corresponding increase in the hard leadership skills such as Management and Business Skills.

Content analysis facilitated another means of objectively evaluating the comprehensiveness of modules based on their descriptive content. The results indicated that the most popular method of integrating a broad range of leadership skills within an individual module was to blend team-project based engineering with a relevant supplementary field such as business or management. Further investigation into the approach utilised by the University of York reinforced this finding. The Electronic Engineering department at York has placed a strong emphasis on active learning and adopted an integrated approach where soft and business management skills like leadership and teamwork are embedded in different modules throughout the degree course. Course designers outlined that the most effective approach was to utilise a project-based learning approach in a group setting, drawing upon engineering skills, business acumen, entrepreneurship, interpersonal skills and professional conduct. The Professional Development Framework introduced in 2018 aims to create 'work-ready' engineering graduates and facilitate their personal effectiveness by promoting a curriculum of professional development skills in their programmes. This proactive strategy develops employability skills including leadership without being overly intrusive, it seems to be a constructive towards formalising the development of essential professional skills among students. Further research could look into a more thorough content analysis of the whole of the UK HE BEng landscape, including case studies of other universities and their programmes so as to establish a more comprehensive view. It would also be constructive to investigate further the views of those in industry towards leadership development along with academics and students in HE. This would contribute to a more holistic understanding of which areas should be considered for further integration, enabling educational institutions to develop a clearer view of industry needs.

Notes

1. BEng - Bachelor of Engineering.
2. The Russell Group is a professional organization that represents 24 leading world-class universities in the UK.
3. MEng - Master of Engineering.
4. The National Student Survey (NSS) is an annual survey in the UK of over 500,000 students, in which respondents are asked to state their honest feedback regarding key areas such as course teaching, assessment and feedback, learning resources, and overall satisfaction.
5. A Chartered Engineer is a protected title registered with, and issued by, the Engineering Council. Issuance of the title demonstrates that the receiver has met the proper knowledge and skills base to assume a position of engineering leadership, accountability and personnel management. See (Engineering Council, 2016).

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