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Understanding professional skills in engineering education: A phenomenographic study of faculty conceptions

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Abstract

Background: Globalization and socially complex problems will greatly affect the way engineers work in the future. Therefore, efforts to transform engineering education must focus on professional skills and engagement of faculty as key change agents.

Purpose/Hypotheses: For engineering programs to address the needs of society, graduates must have the skills to tackle future challenges. Transformation will only be successful if faculty fully engage in all curriculum design aspects; however, little is known about how faculty view professional skills. This understanding is critical if we wish to support and encourage their participation in the transformation effort. This novel study reveals the qualitatively different ways faculty conceptualize professional skills.

Design/Method: Phenomenography was selected as the most appropriate method to showcase the variations in faculty conceptions. The study selected 19 interview participants from 273 responses to an online survey.

Results: Faculty revealed their conceptions of professional skills in six ways: communication skills, technical skills, enabling skills, a combination of skills, interpersonal behaviors, and acting professionally.

Conclusions: Findings revealed a tension between technical and nontechnical skills. The study highlights that engineering education must focus on behaviors and interactions between people rather than technical skills alone. Further, there was a gendered difference in conceptions between women and men with women more likely to consider professional skills to be inclusive of behavioral aspects. The findings can help create future strategies for engineering education and can be used as a reflective tool for engineering faculty in efforts to transform engineering education.

KEYWORDS

faculty development, gender differences, phenomenography, professional skills

1 | INTRODUCTION

Engineers have always been key to addressing societal challenges. The COVID-19 pandemic is a reminder of the world's fragility and highlights the impact of disruptions on global society. Given expected global challenges such as the impact of population increase, urban migration, climate change, economic disruptions, and disruptive technologies (NIC, 2021; United Nations, 2015), engineers of the future must prepare to address socially complex, "wicked" problems (Guerra, 2017; Lönngren & Svanström, 2015; Tejedor et al., 2019; Yearworth, 2016). Thus, there have been calls to embrace transformational change in engineering education (Clarke, 2012; Miller, 2015; Seely, 2005; Sorby et al., 2021; Trevelyan, 2019; Vest, 2008), with much of the focus on the balance of technical and nontechnical skills. However, many reform efforts have fallen short (Royal Academy of Engineering [RAE], 2012; Sorby et al., 2021). Hence, the search for higher education institutions (HEIs) to prepare engineering graduates with the skills to face future challenges continues. Notwithstanding the critical and valued role technical engineering subjects have in an engineering program, a greater focus on the development of professional skills, including communication, teamwork, leadership, and ethics, is warranted (American Society for Engineering Education [ASEE], 2020; Berdanier, 2021; Colman & Willmott, 2016; Gilbuena et al., 2015; Kövesi & Csizmadia, 2016; Miller, 2015; Nair et al., 2009; Passow, 2012; Van Petegem et al., 2016).

One important aspect of how students develop such skills lies in their interaction with faculty. The values and actions of faculty staff with whom engineering students interact are key to determining how a student understands and values various skills they learn and develop (Adams & Felder, 2008; Barrie, 2007). Hence, focusing on faculty and their approaches to teaching professional skills offers a basis for supporting efforts to transform engineering education. However, changes to how faculty teach professional skills may only emerge if the teaching practice aligns with their conceptions of what is important or valuable (Barrie, 2006; Chan & Luk, 2022). Therefore, it is important not only to understand how faculty teach professional skills but also to understand their conceptions of professional skills. It is also vital to understand the variations between their conceptions, to expose faculty to more complete ways of understanding professional skills. Only by noting differing conceptions, discussing them, and coming to a consensus about what is important and why, can faculty begin to design how best to integrate them into engineering programs and teaching practice. There is a gap in the current literature on the variations in conceptions of professional skills, even though it is a prerequisite for supporting changes in academic practice and transformational change in engineering education.

This study contributes to scholarship by highlighting the qualitatively different ways in which faculty conceptualize professional skills. The work builds on prior studies (Barrie, 2006; Chan & Luk, 2022) by furnishing insight into different conceptions and the key factors that differentiate those conceptions. Resources to support transformational efforts for educators with different beliefs are needed (Chan & Luk, 2022) and the findings can be used by engineering educators as a resource to consider how they can move from one conception to another by reviewing and reflecting on the variations. By understanding the variations in conceptions, faculty can influence changes in teaching practice and curriculum design by aligning specific initiatives with their varying conceptions (Barrie, 2007). Improved teaching practice, coupled with an enhanced curriculum and new learning activities, offers engineering students the best opportunity to develop excellent professional skills. This study provides an outcome that can be used to support the professional development of engineering educators, leading to improved teaching practice and subsequently better student performance (Darling-Hammond et al. (2009), thereby better preparing graduates to face and overcome future challenges.

2 | LITERATURE REVIEW

The engineering profession has changed dramatically since its origin, and engineers today must work with other people in diverse, multidisciplinary international teams, as the skills needed to succeed go far beyond mere technical skills (ASEE, 2020; Bae et al., 2021; Byrne & Mullally, 2014; Chan et al., 2017; Craps et al., 2017; Kolmos & Holgaard, 2019; Tejedor et al., 2019; Winberg et al., 2018). The debate on skills requirements in engineering programs is not new and the discourse about the lack of skills has been ongoing in professional bodies since 1955 (ASEE, 2018; Grinter, 1955; RAE, 2007; Spinks et al., 2006). The seminal Henley Report (Spinks et al., 2006) commissioned by the RAE has not ignited the educational transformation that was intended, as there remains recent calls from professional bodies on the lack of adequate skills in engineering graduates (ASEE, 2020; IET, 2019). Industry has a similar viewpoint to the professional bodies (Colman & Willmott, 2016; Husain et al., 2010; Kövesi & Csizmadia, 2016; Nair et al., 2009; Sageev & Romanowski, 2001). Employers recognize that the future is in flux, and, as such, the engineer's role must change along with the required skill set.

Many studies focus on specific professional skills and their importance, typically falling into two categories. The first includes systematic literature reviews or meta-analyses to identify the skills engineers need (Beagon et al., 2019; Markes, 2006; Passow & Passow, 2017; Pons, 2016; Winberg et al., 2018). Passow and Passow (2017) provide a comprehensive list of generic engineering competencies along with their relative importance in various studies. However, they report that the variation in understanding of the terms used proved troublesome in the review. The ASEE (2013) undertook a seminal and wide-ranging study on the graduate engineer of the future. They propose a T-shaped engineering graduate, with a broad knowledge base and deep technical expertise in a particular area, and the ability to work within a diverse team. Recent focus has shifted to the required skills to achieve sustainable development and meet the Sustainable Development Goals (Beagon et al., 2022; Brundiers et al., 2021; Redman et al., 2021; Rieckmann, 2012; Segalàs Coral et al., 2018; Wiek et al., 2011), and work is underway to map existing programs against required skills (Albareda-Tiana et al., 2020; Crean et al., 2021; Segalàs Coral & Sánchez Carracedo, 2020).

The second type of study lists predetermined skills to ascertain which is most important. They include surveys distributed to engineers working in the field (Le & Tam, 2008; Male et al., 2011; Passow, 2012) and employers (Colman & Willmott, 2016; Husain et al., 2010; Kövesi & Csizmadia, 2016; Nair et al., 2009; Ridgman & Liu, 2014). Among the many skill lists, some use similar terminology for different meanings, and many terms are used to describe the list of skills: graduate attributes, soft skills, employability skills, key skills, transferable skills, generic competencies, holistic competencies, generic skills, professional skills, nontechnical skills, and transversal skills (ASEE, 2020; Barrie, 2007; Berdanier, 2021; Chan et al., 2017; Chan & Luk, 2022; Craps et al., 2017; Dacre Pool & Sewell, 2007; Fernandes, 2014; Husain et al., 2010; Iborra et al., 2014; Khan et al., 2016; Litchfield et al., 2016; Male et al., 2011; Markes, 2006; Passow & Passow, 2017; Pons, 2016; Shuman et al., 2005; Winberg et al., 2018).

One of the key findings from the literature is the extent to which different terminology is used to describe the skills engineers need and the dissonance between whether professional skills include technical skills or are something different. Berdanier (2021) warns of the importance of using terminology carefully and highlights that the use of "soft skills" demotes the value of these types of skills. In 2020, the ASEE (2020) conducted a survey to assess the skills gap experienced by engineering graduates as they enter the workforce, with the goal of providing suggestions to educators on how to better prepare students for their future careers. The survey questions were divided into two main categories: professional skills and technical skills. This suggests that the ASEE recognizes professional skills as distinct from technical skills (ASEE, 2020). According to the ASEE study, professional skills are defined as those essential to thrive in a work environment but not historically emphasized in engineering coursework. Examples include communication, emotional intelligence, teamwork and multidisciplinary work, curiosity, project management, critical thinking, self-drive and motivation, cultural awareness, and high ethical standards (ASEE, 2020). Others use professional skills to mean teamwork, motivation, communication (Van Petegem et al., 2016), project management, leadership, self-awareness (Gilbuena et al., 2015), or people skills, such as attitudes and behaviors and not just technical knowledge (Miller, 2015). This focus on people skills and attitudinal behavior is important, as it acknowledges the need to transform the engineering community to be more collaborative and inclusive of gender, race, ethnicity, and sexual orientation (Sorby et al., 2021). For comparison, technical skills have traditionally been associated with a fundamental understanding of materials and engineering science, as well as proficiency in mathematics and computing and the ability to identify, formulate, and solve engineering problems. However, in recent years, technical skills have evolved to encompass new and emerging fields such as augmented reality, artificial intelligence, digital twins, systems integration and systems thinking, internet of things, data analytics, cyber security, and robotics, among others (ASEE, 2020).

The National Science Foundation engineering education research (EER) taxonomy (Finelli et al., 2016) proposes that professional skills is given an equal hierarchical level to other outcomes such as communication, critical thinking, ethics, and teamwork, suggesting that professional skills do not include these aspects. One of the most influential publications on professional skills are those listed as six outcomes in the ABET engineering criteria (ABET, 2019; Miller, 2015; Mutalib et al., 2013; Shuman et al., 2005), which are also at odds with the EER taxonomy regarding the hierarchical position of lifelong learning, communication, ethical responsibility, and teamwork. These examples demonstrate an inconsistency in terminology and interpretation conceptually, though they are often used interchangeably in the literature. This study does not attempt to synthesize all the skills, explain the differences between terms used, or produce a definitive list of skills, as that is not the focus of the study. Indeed, many studies focus on the skill types that are important and effective teaching pedagogies for different skill sets (Ahern et al., 2019; Shuman et al., 2005; Winberg et al., 2018). Nonetheless, this study employs the term "professional skills," as it is considered a more inclusive term (Berdanier, 2021), and to reflect the context and language of the study location setting.

If the transformation of engineering education centers on teaching students new skills, HEIs are key to the transformation effort. Several authoritative figures have called for curricula redesign (Clarke, 2012; Miller, 2015; Trevelyan, 2019; Vest, 2008). Phrases such as "rebalancing engineering education," "reinventing the wheel," "embracing transformational change," and "engineering education needs a revolution" are all used in relation to reform (Clarke, 2012; Miller, 2015; Seely, 2005; Sorby et al., 2021). There have also been reports to examine why attempts to transform engineering education are often unsuccessful, with one reason identified as a lack of faculty engagement (RAE, 2012). Understanding how faculty members think and connecting with faculty members is essential to enacting change within academic practice (Barrie, 2006; Borrego et al., 2010; Chan & Luk, 2022).

The authors acknowledge the importance of determining skills and assessing different teaching approaches; however, the missing link is the faculty member in the center, the person who translates this research into practice. Top-down approaches such as program reviews, accreditation requirements, industry reports, and governmental policy changes can certainly influence what is taught in the classroom (Chan & Luk, 2022). However, it is also important to consider the hidden curriculum (Biggs & Tang, 2007; Trevelyan, 2019; Villanueva et al., 2018) or, more specifically, how specific aspects are taught by the faculty in the classroom. Faculty interactions with students and the value they place on aspects of the curriculum are influenced by their differing conceptions and contexts (DeMonbrun & Brown, 2014). For example, if a faculty member makes light of a particular topic, students may perceive that it is unimportant. Their actions, consciously or not, can affect the student learning experience and outcomes. The hidden curriculum can be considered as the attitudes, knowledge, and behaviors faculty can convey or communicate to students without conscious intent (Alsubaie, 2015).

Two studies are particularly noteworthy regarding previous research and emphasis on what faculty think or believe about professional skills. The first, based in Australia, focuses on "graduate attributes" and how they were conceptualized by faculty from multiple disciplines (Barrie, 2006, 2007). Chan and Luk (2022) investigate the beliefs of engineering academics in Hong Kong about "holistic competencies," highlighting the importance of this type of research work to support the transformation effort. Interviews with six engineering faculty were analyzed thematically to reveal academics' beliefs about teaching practices, the value of holistic competencies, and the contextual factors affecting their beliefs. The study revealed a dichotomous view between holistic competencies and academic (technical) competencies with a superior view of academic competence linked to the Confucian culture. Chan and Luk (2022) note the impact academics' beliefs can have on education reform and call for additional research on the gaps between current faculty beliefs and the conceptions required to support the transformation effort.

Barrie (2007) shows an internally consistent link between academics' understanding of generic attributes and how they were taught in the classroom. Seely (2005) attests that reform motivation generally stems from issues people consider important. Thus, to induce a person to change, the initiative for change must align with their perspective of what is important. The importance of focusing directly on faculty (key change agents) cannot be underestimated, as attempts at transformation are unlikely to be successful if they do not correlate with the understanding of those to whom they are directed (Barrie, 2006; Chan & Luk, 2022; Kember & Kwan, 2002).

In recent literature, most engineering education work investigating professional skills development focuses on lists of skills (Colman & Willmott, 2016; Husain et al., 2010; Kövesi & Csizmadia, 2016; Nair et al., 2009; Sageev & Romanowski, 2001), the importance of specific skills (Beagon et al., 2019; Le & Tam, 2008; Male et al., 2011; Markes, 2006; Passow, 2012; Passow & Passow, 2017; Pons, 2016; Ridgman & Liu, 2014; Winberg et al., 2018), skills for sustainability (Beagon et al., 2022; Brundiers et al., 2021; Redman et al., 2021; Rieckmann, 2012; Segalàs Coral et al., 2018; Wiek et al., 2011), or review of curricula for integration of specific skills (Albareda-Tiana et al., 2020; Crean et al., 2021; Segalàs Coral & Sánchez Carracedo, 2020) showing that there is an appetite for transformation of engineering education in regard to improving opportunities for engineers to develop excellent professional skills. However, given that faculty members are central to the practice of education, and their actions have a significant impact on generations of future engineers, it is important to focus on engineering faculty (Barrie, 2007; Chan & Luk, 2022). A gap in the engineering education literature exists as to how engineering faculty conceptualize what professional skills are and, thus, their value in the engineering curriculum. Hence gaining a deep understanding of the differing conceptions of professional skills and the variations between them is a fundamental basis for supporting transformation in engineering education.

3 | POSITIONALITY STATEMENT

For transparency, we would like to highlight the positionality of the researchers involved in this work. The first author undertook all interviews and led the analysis work. As a reflective researcher and an instrument in the data collection, the first researcher is aware that their demographic identity and experiences mean that they assume a perspective to conduct this research. They are a White female engineering academic currently working at an Irish University. As head of a discipline, they are responsible for program design and work closely with a team of faculty staff. They have 20 years of industry experience including roles at Director level where they were responsible for recruitment, mentoring, and promotional decisions for engineering staff in Ireland and the United Kingdom. Their experience of mentoring graduates helped them value the importance of professional skills for promotional opportunities.

Since joining academia, they have been concerned about the gap between the technical focus of an engineering curriculum and the wider skill set engineers need to have a successful career. They acknowledge that they are an insider in the participant community as a member of the engineering faculty with an emic view, which helps them grasp the context of the belief systems, culture, and practices in the community. This study aims to unpack the engineering faculty conceptions such that, in their current role, where they can influence program design and mentor colleagues, they can bridge the gap between what currently happens in the classroom and what engineering students need for the future. They consider that meaning is created through our interaction with the world, and as individuals we experience social phenomena in different ways. Hence, they approached this study from an interpretivist ontological position and a constitutional epistemological perspective. Specifically, they used interviews as the main form of data collection because they placed value on interpreting people's experiences by listening to their accounts of those experiences.

The second author, a White male with a science, technology, engineering, and mathematics (STEM) background, is an established member of the engineering education community who focuses on quality, curriculum development, enhancement, and pedagogy. With experience in undertaking EER using various methodologies and supervising research studies, they worked closely with the first author to define research questions, develop the methodology, and review pilot interviews, providing feedback on interviewing techniques. Further, they served as a critical soundboard, ensuring the findings were strongly supported by the data through regular meetings with the first author to review, discuss, and question each of the findings. These meetings, which were used to confirm the analysis, were effective in reducing potential bias given by the first author's positionality and background.

4 | RESEARCH METHODOLOGY

Phenomenography was first pioneered by Marton and colleagues at Göteburg University in Sweden in the 1970s; the term was coined in their seminal paper (Marton, 1981). Marton (1986) describes phenomenography as a research method that maps the qualitatively different ways in which people experience, conceptualize, perceive, or understand phenomena. It explores the relationship between a person and a phenomenon, that is, how that person experiences it, what is termed a nondualist, second-order perspective (Marton, 1981). The research object is not the phenomenon itself (such as in phenomenology) but the relationships between the people (subject) and the phenomenon (object) (Svensson, 1997). Hence, the description of experiences and their underlying meaning are vital. Phenomenographers seek qualitatively different but logically interconnected descriptions of people's experiences in a particular context (Marton, 1994).

Although the goal of a phenomenographic study is to describe peoples' experiences and highlight the qualitatively different ways in which they experience a phenomenon, scholars have described multiple approaches to implementing the phenomenographic methodology (Åkerlind, 2005a; Green & Bowden, 2009; Marton, 1986; Mendoza-Garcia et al., 2020). These approaches can differ in both the data collection process and procedures used in the stages of analysis, and Åkerlind (2005b) provides a comprehensive account of the accepted commonalities and variations in phenomenographic approaches. This study drew on data collection and analysis methods described by Åkerlind (2005a), Green and Bowden (2009), and Marton and Booth (1997). Mendoza-Garcia et al. (2020) refer to this type of approach as "Blended Phenomenography," a methodology that combines the best features of different approaches to address challenges related to data collection, reaching saturation and identifying variation. While the analysis process is described later in detail in this study, it is important to note the blended nature of our approach at this point.

Variation theory (sometimes referred to as new phenomenography) was proposed as a theoretical foundation for phenomenography (Pang, 2003) to defend this new approach against early criticism (Richardson, 1999; Säljö, 1996; Säljö, 1997). It is through variation in experience that people discern which features are important or valued and those that are unimportant. Marton and Booth (1997) explain that people do things differently; thus, they must have learned to do so with some doing it well and others not doing it so well. Therefore, the process of learning requires the ability to see variation and distinguish between different aspects (Trigwell, 1999). By distinguishing different aspects, one can consider how to do things better. Research outputs of phenomenographic studies are called outcome spaces, which showcase a logically related set of categories of description, each describing a qualitatively distinct way of experiencing a phenomenon. Each successive category of description provides an in-depth description of how the phenomenon was experienced, differentiated by themes of expanding awareness to show the variations (Åkerlind, 2005a).

This study aims to produce outcomes that can be used as a resource for engineering educators to allow for developing an appreciation of the differing (and more complete) ways of conceptualizing professional skills. Hence, the outcome can serve as a learning and teaching tool for competence development (Larsson & Holmström, 2007). Reimers et al.'s (2015) argument that effective professional development for engineering educators can lead to improved teaching practice and subsequently better student performance is supported by research. Studies such as Darling-Hammond et al. (2009) have found a positive correlation between effective teaching practices and improved student outcomes. Therefore, it is essential to provide resources for educators to support their professional development. Reimers et al. (2015) suggest that effective professional development should allow learners to review and improve on their own misunderstandings and provide insight into false beliefs or misconceptions they may hold. Reflective practice is also an essential habit of mind for educators, as advocated by Adams and Felder (2008). A resource that enables educators to reflect on their own conceptions and build more comprehensive understandings of relevant phenomena is therefore valuable.

Outcomes of a phenomenographic study are suited to this purpose and this can be described as developmental phenomenography (Bowden, 1995; Green & Bowden, 2009), where the study outputs are used to address a particular (often educational) issue, unlike pure phenomenography, which is driven primarily by curiosity (Green & Bowden, 2009). Notably, given the aims of this study and the use of phenomenography as a research methodology, the core research question is as follows: What are the qualitatively different ways that faculty teaching on engineering programs in Ireland conceptualize what is meant by professional skills in engineering?

4.1 | Context

At the time of this study, Ireland had 14 Institutes of Technology (IoTs) and seven traditional universities, with all but one offering engineering programs. The IoTs were established in the 1970s as Regional Technical Colleges (RTCs) to provide vocational education. In the 1990s, they were upgraded to IoTs to reflect the high standards and university-level research that was being undertaken in these institutions (Higher Education Authority [HEA], 2021). Recently, in response to legislation enacted in 2018, the IoTs began a merger process aimed at creating five new technological universities in Ireland. The consolidation is intended to improve Ireland's ability to meet national strategic needs (HEA, 2021).

According to a recent survey in Ireland, 87% of faculty teaching engineering programs have an engineering degree and 82% have industry experience before joining academia (Beagon & Bowe, 2019). Furthermore, academics teaching on science, technology, engineering, mathematics, and medicine [STEMM] programs in Ireland were 41% female (HEA, 2019). However, only 19% of faculty were female in one university when granulated to engineering and built environment programs specifically (TU Dublin, 2018). The same faculty (mainly engineers) typically teach all modules in the program, including those associated with communication skills and professional practice. Staff from social sciences or other faculties are not typically brought in to teach such modules as is the norm worldwide. The interviews conducted as part of this study surveyed faculty currently teaching engineering programs in Ireland, most of whom are engineers. It is also important to highlight some demographics regarding race to give a picture of the context from which the faculty involved in this study are drawn (Pawley, 2017). In 2021, the HEA in Ireland undertook a national survey to develop a picture of race equality in the Irish higher education sector (Kempny & Michael, 2021). The survey respondents (academic staff) spanned a race profile of White Irish (72%), White Other (17.5%), Asian or Asian Irish (3.1%), Black or Black Irish (1.7%), Mixed Group/Background (3.3%), and Irish Traveler and Roma (0.5%) (Kempny & Michael, 2021).

4.2 | Data collection

Marton and Booth (1997) propose that phenomenography is not a method but an approach, as methods are subordinate. Hence the core of this research study involved phenomenographic interviews to elicit participants' experiences. However, an online survey was initially used to create a data pool of potential interviewees from which a purposeful sample of participants was selected (Beagon & Bowe, 2019). Survey questions included the extent of industrial and academic experience, the experience of working with graduates, Approaches to Teaching Inventory (ATI) (Trigwell &

Prosser, 2004), educational and research qualifications, and involvement with Engineers Ireland (Accrediting Body). A rigorous method was employed to select participants for the interviews for a maximum variation of experiences (Appendix A describes this process in depth) (Kellam & Cirell, 2018). In summary, participants included 9 women and 10 men, with 14 of them working in IoTs and five in universities in Ireland. Participants were chosen based on atypical responses to questions within the survey for maximum variation. For example, if most respondents had worked in academia for between five and 20 years, then those who had worked for less than 5 years or more than 20 years were considered atypical. Table 1 presents key demographics of the interviewees. See Beagon (2021) for the full survey.

Pilot interviews were carried out to confirm that the interview questions were framed correctly and provided answers that reflected participants' experiences in relation to the research questions (Ashworth & Lucas, 1998). Four pilot interviews were carried out sequentially, allowing the researcher to review, discuss, and improve on the quality of interview questions after each pilot, particularly regarding follow-up questions, thus ensuring the interviewer gained a sense of the conceptual meaning behind some of the terms used (Sin, 2010). This review and reflection process was important to help address the quality of the research process itself, not only in terms of handling the data but also in terms of making sense of the data (Kellam & Cirell, 2018). Sin (2010) describes it as reflexivity, where the researcher identifies any preconceptions and takes measures to systematically minimize their influence on the process. Appendix B provides the interview template, including key questions and suggested follow-up questions. The interview focused on two phenomena: faculty conceptions of professional skills (this study) and their approaches to teaching

TABLE 1 Key demographics of interviewees.

Pseudonym name	Gender[a]	Extent of industrial experience	Outlier ATI results[b]	PhD qualification	Educational qualification[c]	Extent of academic experience	Main role (lecturing/ research)
Dermot	Male	>20 years				5–10 years	L
Hannah	Female	None	ITTF		PGCert	11–20 years	L
Nathan	Male	>20 years	CCSF	PhD		5–10 years	L
Muireann	Female	11–20 years			PGDip	<5 years	L
Nichola	Female	11–20 years	ITTF&CCSF			<5 years	L
Kathleen	Female	6–10 years			MA	>20 years	L
Sean	Male	11–20 years		PhD		<5 years	L
Charlie	Male	11–20 years	CCSF			>20 years	L
Sebastian	Male	>20 years		PhD		<5 years	R
Josephine	Female	6–10 years				11–20 years	L
Greg	Male	None		PhD		5–10 years	R
William	Male	0–5 years		PhD		>20 years	R
Rosaleen	Female	None			MA	>20 years	L
Christina	Female	11–20 years		PhD		11–20 years	L
Imelda	Female	11–20 years				<5 years	L
Joe	Male	None				>20 years	L
Monica	Female	0–5 years		PhD		<5 years	L
Mike	Male	None		PhD	PGDip	11–20 years	L
Adrian	Male	Information is not available for Adrian as they were one of the pilot interviews that were included and did not complete the survey					

[a]Self-reported options for gender provided on the survey included male, female, or other/prefer not to say. However, it is noted that it would be more appropriate to have provided terms such as man, woman, or other/prefer not to say for this question in line with good practice and the principles of bias-free language.

[b]Respondents were asked to complete the Approaches to Teaching Inventory (ATI) (Trigwell & Prosser, 2004) within the survey. Scores greater than 26 out of a maximum score of 32 were identified as outliers either in the Information Transfer/Teacher-Focused (ITTF) or Conceptual Change/Student-Focused Scales (CCSF). Blanks in this column indicate that the ATI response was not in the outlier range.

[c]This column indicates whether respondents have completed a formal qualification in education; PGCert—Postgraduate Certificate, PGDip—Postgraduate Diploma, MA—Master of Arts.

professional skills (Beagon & Bowe, forthcoming). In a final analysis, we probed the relationship between faculty conceptions and their subsequent approaches to teaching (Beagon & Bowe, forthcoming).

Phenomenographic interviews focus on interpreting participants' experiences; thus, rather than asking about professional skills, many of the questions ask participants to describe situations and present follow-up questions to investigate why or how the participant addressed the situation. The interpretation of such experiences is the focus of a phenomenographic study. The interviews were all undertaken by the first author for consistency in how the questions were asked and how the responses and subsequent prompts were provided (Green & Bowden, 2009). While some texts suggest 25–30 interviews (Green & Bowden, 2009), others suggest that 10–20 interviews are sufficient for saturation (Åkerlind, 2005b; Bowden, 1996; Trigwell, 1999). In practice, we checked for saturation once we had created our categories of description by checking randomly ordered transcripts and mapping how many transcripts were needed to identify all categories. We did this randomly three times and confirmed that all categories were identified in the first three, four, and seven transcripts. Therefore, we were satisfied that we had achieved saturation with 19 interviews.

4.3 | Analysis

All interviews were recorded and fully transcribed, following recommendations from Marton (1986), Green and Bowden (2009), and Åkerlind (2005a). A blended approach was used in regard to the methods of analysis in order to overcome challenges and difficulties associated with different analysis methods. Mendoza-Garcia et al. (2020) describe these challenges and present a blended approach to address difficulties such as trying to reach saturation when following methods outlined in Marton (1986) and Green and Bowden (2009), and weaknesses in defining the hierarchy of an outcome space if it is based on judgment alone (Marton, 1986) and not empirical evidence (Åkerlind, 2005b). They describe a new approach "Blended Phenomenography" that utilizes what they term Marton's second phenomenographic approach (Åkerlind, 2005b; Pang, 2003) for the data collection (interviews) and first part of the data analysis phase. In practice, this describes how utterances relevant to the research question are extracted into a pool of meanings and a set of stable dimensions of variation are created independent of individual participants. Then they turn to Bowden's developmental approach (Åkerlind, 2005b; Green & Bowden, 2009), which uses the whole transcript to help create the hierarchical relationship of the outcome space using empirical data. A similar methodology using a blended approach was used in this study, and Figure 1 presents a flow diagram indicating each iterative step used to analyze the transcripts. Each step is described in depth (Beagon, 2021) to provide a full and open account of the analysis process (Cope, 2004). The analysis spanned several months, sometimes with large gaps between stages, as teaching loads increased within semesters. In retrospect, these gaps were invaluable, as a fresh set of eyes allowed for questioning the validity of analysis decisions in previous iterations. The phenomenographic interviews were analyzed in two phases.

The first phase (Figure 1: Steps 1–6) created categories of description describing the qualitatively different ways faculty conceptualize professional skills. The analysis process began by reviewing the transcripts looking for criteria of relevance. Marton (1986, p. 153) describes these excerpts as "utterances" that relate to the question being probed. The first author initially read the transcripts several times and extracted utterances that were relevant to the research question. The selected quotes comprised a data pool from which the first author then turned away from referring to individual subjects and attempted to determine the meaning embedded in the utterances themselves (Marton, 1986).

At this point, it is important to explain some of the variations in phenomenographic data analysis to justify the study methods. Åkerlind (2005b) provides an in-depth comparison of variation in techniques in managing and analyzing the data, constituting the structure and the different approaches to validity and reliability used by phenomenographic researchers. First, practice varies per researcher regarding the amount of each transcript considered at a time. Some prefer to consider whole transcripts at once (Åkerlind, 2005a; Bowden, 1995), others prefer to select smaller quotations that directly represent specific meanings (Marton, 1986). Both recognize the importance of interpretation within the larger interview context. The recommendations by Marton (1986) were employed in the initial review of manuscripts for three reasons. First, we wanted to reduce the risk of focusing on individual interviewees and their meanings rather than meaning derived from the whole group. Second, it became clear in the first few transcript readings that some interviewees expressed more than one way of experiencing the phenomenon; thus, the purpose was to separate them and treat them with equal value. Finally, we aimed to manage the data as the extraction of utterances of relevance brought clarity to the analysis without the distraction of irrelevant text (Åkerlind, 2005b). Quotes were grouped into categories based on similarities between meanings in quotes, with boundary cases highlighted in each group. Via an iterative procedure, the first author determined a tentative set of categories of description where each

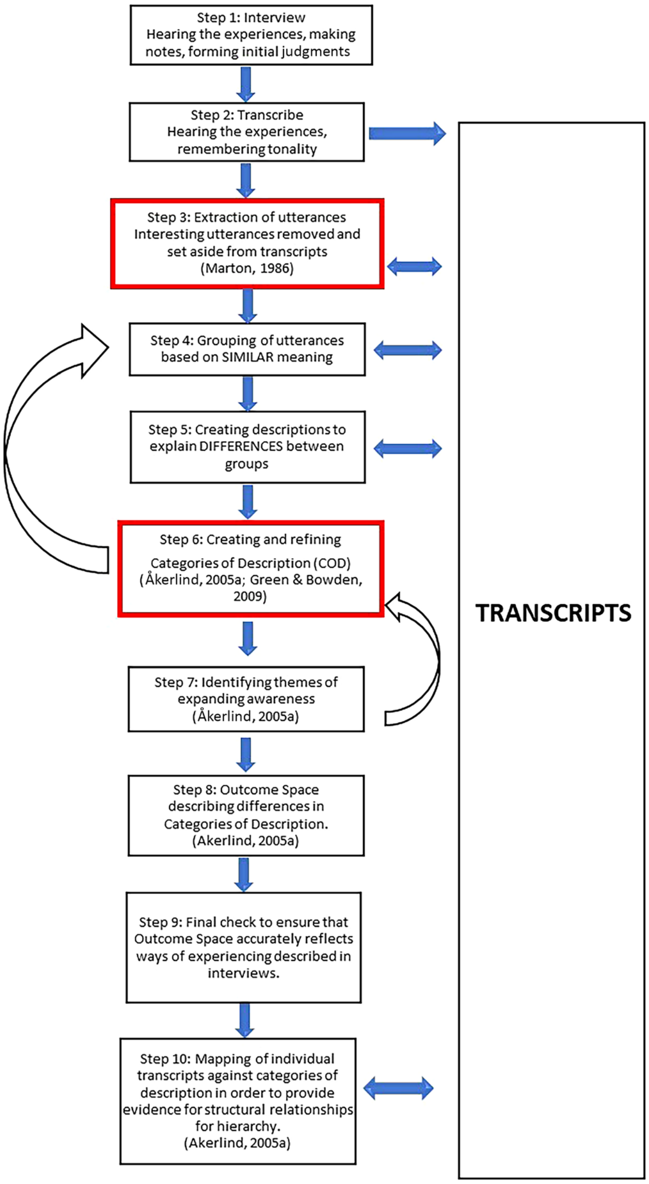

FIGURE 1 Flow diagram showing the process of analysis of interview data.

category was differentiated from another relative to its differences from others. Once the first author had completed a draft of the categories of descriptions, the second author undertook a similar exercise with a selection of transcripts. We then employed the devil's advocate approach to question and defend each iterative category description, seeking clear and contextualized evidence from the transcripts (Åkerlind, 2005a; Green & Bowden, 2009).

The second phase (Figure 1: Steps 7–9) created the outcome space to describe the logical relations and hierarchy between the categories of description. That is, the outcome space shows how each category of description relates to each other and which represents more complete ways of conceptualizing professional skills, given the themes of expanding awareness. Åkerlind (2005a, p. 122) describes themes of expanding awareness as "representing structural groupings of dimensions of variation" (i.e., a variation that appears in each category but at different levels). The process of continual reading, sorting, and resorting of quotes over several months had many iterations that initially included several dimensions of variation, some of which were discounted, as they were not critical (i.e., they did not differentiate between categories). For example, a theme that emerged in the analysis related to where professional skills were learned, including "learned as a student," "learned in the workplace," or "learned in life." We identified a range of where professional skills were learned in each category (but not specific to one category); therefore, this theme was not a critical aspect of differentiation across categories. We followed recommendations from Åkerlind (2005a) that the theme be apparent in each category of description constituted and that different levels along the theme distinguished between different categories of description in order that the outcomes would be of use in describing how one might transition from one way of experiencing to another.

The recommendations by Åkerlind (2005a) were also used in the final step, which sought to develop the hierarchical relationship. In this case, both empirical data and the researchers' experiences helped to assess the hierarchical nature of the categories. Åkerlind (2005a) expresses the extremes of creating structural relationships by focusing on logical structures or empirical evidence, arguing for a combination of both as most appropriate. This study considered both aspects in creating the hierarchy. Once the categories of description had been determined, some of the themes of expanding awareness were clearly hierarchically superior to others. For example, as they progressed in each theme, they were additive: technical skills, nontechnical skills, and technical and nontechnical skills. Examples of the theme of benefit include personal benefit, personal and industry benefit, and personal, industry, and societal benefit. We also mapped each interview transcript against each of the categories of description to support the empirical data analysis and obtain empirical evidence that interviewees aligned to a high-level category of description may also encompass lower levels of categories, and those aligned with lower levels were unlikely to exhibit higher level categories (Åkerlind, 2005a). Accordingly, we identified which categories of description were revealed by each interviewee; thus, their pseudonyms are associated with individual quotes.

4.4 | Research quality considerations

Quality in phenomenography is often a contentious issue (Cope, 2004; Sandberg, 1997; Trigwell, 2006). Sin (2010) describes some key issues of quality in phenomenographic studies, the first of which is to ensure internal consistency between the research method, the study object, and the findings. Hence, this study's aim to better understand faculty conceptions of a socially complex phenomenon fits into the phenomenographic research approach. Marton (1986) attests that reliability (the extent to which findings can be replicated) is inappropriate for a phenomenographic approach. As the categories of description are discovered by the researcher, the discovery is not replicable; however, it is reasonable to suggest that once these categories have been found, other researchers can agree on them (Sandberg, 1997). We used this approach to ensure the robustness of the findings.

Admittedly, it is challenging to be objective (Kellam & Cirell, 2018; Kinnunen & Simon, 2012; Sin, 2010). During the data collection (interview) process, we were especially mindful of bracketing any previous experiences or assumptions so as not to bias the interview or follow-up questions (Åkerlind, 2005a; Ashworth & Lucas, 1998; Green & Bowden, 2009; Sin, 2010). The first author was mindful to set aside prior assumptions and presuppositions from studies on professional skills, particularly regarding the skill types typically mentioned in the literature and the tension between technical and nontechnical skills. For example, there was an occasion in an interview when a participant described a disturbing situation of speaking at a meeting where they were ignored and spoken over. The first author made a conscious effort to listen carefully and try to understand the experience of the interviewee, rather than relating the experience to similar events in their own work life. In practice, it meant keeping a neutral tone in the interview and avoiding facial expressions to keep in check the potential for prejudice to intrude in the interview (Sin, 2010).

However, we recognize that an outcome space is constituted in a phenomenographic study and Åkerlind (2005a) describes a robust constitution process as including both empirical data and the researchers' experiences; hence, in the analysis process, we did not bracket our previous experiences but used them to constitute the outcome space. In fact, Marton (1986) recognizes that phenomenographers can use immediate experience and conceptual thought because they are seeing and recognizing the variation based on their own awareness of the variation of the phenomenon under investigation. However, being mindful of potential biases and wishing to create a robust output, the two authors met to discuss and defend each finding (Bowden et al., 1992). Via testing against the data, adjustment, retesting, probing, and regular discussions over several months, ensuring that interpretations were backed up by specific transcript utterances, we reached a consensus on the categories of description (Åkerlind, 2005a; Green & Bowden, 2009).

4.5 | Ethical process and consent

Approval was granted by the TU Dublin Research Ethics and Integrity Committee (REIC-18-94) for the survey and interviews of this study. Furthermore, to ensure the trustworthiness of the findings, once the interviews were transcribed, we sent the transcripts to the interviewees for their review and approval. At that time, we had anonymized and redacted any revealing characteristics to prevent any participant identification. Each interviewee was allocated a pseudonym (chosen by the interviewer); thus, when quoting specific participants, their anonymity was assured.

4.6 | Limitations

A phenomenographic research design with a robust validity and reliability process allowed the outcome spaces to emerge organically. However, it is also important to note the limitations of the study. The outcomes are contextual to faculty teaching engineering programs in Ireland and, thus, are not representative of all engineering faculty, as language and local social and political factors can be influential. For example, the term "professional skills" is often used in the US literature to refer to specific ABET competences that are nontechnical skills, but this influence is not as impactful in Europe with different accrediting bodies. Local contexts, including the type and focus of the HEIs involved in the study, may be limiting factors. For instance, IoTs in Ireland often have a practical focus on their curricula relative to universities, which can be more theoretical. Faculty in IoTs have a heavy lecturing load (typically 16 contact hours per week) relative to those in universities that typically have 6–10 contact hours and are more focused on research output (Beagon & Bowe, 2019). These institutional and structural factors can impact the value faculty places on their teaching load and the type of skills they wish to impart during that time. Although this study included faculty from IoTs and universities in Ireland, the context outside of Ireland may be different. The focus of HEIs may also impact how faculty approach their relationship with students. Faculty who work in traditional HEIs with teacher-focused pedagogies may have a different view from those working in problem-based-learning-focused universities that may espouse more student-centered approaches.

Furthermore, we did not collect information on the race of the respondents to the survey and, thus, did not select participants for racial diversity. While we were mindful of gender diversity, we cannot illuminate the ethnic diversity of the participants in the study.

5 | FINDINGS

We use tabular and graphical presentations to demonstrate the logical relations between each category of description to better understand the variation in conceptions of professional skills. Through the iterative process in Figure 1, three themes of expanding awareness were identified regarding conceptions of professional skills: *the purpose* of developing professional skills, to *whose benefit* the professional skills are, and the *types* of skills or behaviors described. In other words, these themes emerged as those that differentiated each category of description from each other and are used to show the structural nature of the outcome space. Only themes of expanding awareness that were apparent in each category are included in the present study following recommendations of Åkerlind (2005c), as this is seen as important to ensure useful outcomes, giving an insight into the transitions between categories. The themes of expanding awareness describe and distinguish the participants' conceptions of professional skills.

5.1 | Categories of description—Professional skills

Six categories of description revealed in the data are as follows:

A. Communication skills.
B. Discipline-specific technical skills.
C. Skills that enable a person to be a successful engineer.
D. A combination of discipline-specific technical and nontechnical skills.
E. Interpersonal behaviors to build successful relationships with people.
F. Acting professionally toward people and society.

The categories are qualitatively different, based on the themes of expanding awareness. Each category of description is now described relative to the three themes of expanding awareness along with associated utterances from the data.

5.1.1 | Category A—Communication skills

Category A represents a view of professional skills as those skills needed to communicate only. This category includes written communication in the form of reports, verbal communication in the form of presentations, and communicating effectively in meetings. Interviewees see good communication as beneficial to the person themselves. Speaking and becoming confident in communicating one's voice are crucial foci of the interviewee's awareness in this category. Hannah provides a simple definition of professional skills as communication skills. The skills are not discipline-specific engineering skills but are generic skills, independent of the discipline (non-discipline-specific skills):

> "Well, I would say professional skills [are] your communication skills, your writing skills, your presentation skills, you know those types of skills."—Hannah

> "Professional skills are the skills … that all students regardless of discipline need to be comfortable with and be familiar with."—Hannah

Monica also describes professional skills as communication skills but explains the nuances of the different types of communication styles needed to speak to people on different levels.

> "The ability to communicate effectively, with not just your colleagues or your peers but to communicate to somebody senior and communicate to somebody junior because we're all the time talking to people at different levels."—Monica

Moreover, this category is also used to describe how engineers find their voice. Learning to stand up for themselves in meetings is mentioned several times by women, highlighted here by Muireann and Imelda. In this instance Muireann, though referring to a workplace incident, is focusing on their voice and learning to be heard for their benefit, not necessarily for the benefit of the workplace.

> "But to be able to articulate what you need. Now, I would say for me and if you were to say from a female perspective, I would've sat in endless meeting rooms where I'm the only female voice. So, the simple thing … and maybe that's why I'm going into spontaneous speaking and how you come across when you speak because a few times I might have said something and either the room would just continue on with the chat because they haven't heard what I said or I haven't said 'Excuse me', you know, politely, maybe too politely. But then when I say 'Excuse me' again, and then because of the different tone, everything goes dead and they're all looking at you and what do you do?"—Muireann

Imelda describes the importance of learning the skills of communication to talk to people appropriately and stand up for yourself.

> "You learn through working as well. You learn to be able to, especially whenever you're in a male-dominated industry, you also learn how to be professional and talk to people but still stand up for yourself because I've been in a room with maybe 20 men, all a lot older than I was. I'd have been what? 24 or 25. And a lot of them would have had no respect for you. I sort of developed and learned myself—where's the boundary, what to say, what not to say—but still firm enough to stand up for me."—Imelda

5.1.2 | Category B—Discipline-specific technical skills

Accounts consistent with this category highlight the importance of discipline-specific technical skills. These skills are the discipline-specific skills needed to be an engineer: the core technical skills engineers use. The benefit in this case is for industry: these technical skills are being taught for engineers to serve industry: industry is the object of focus.

Dermot, when describing professional skills, explains the importance of really understanding the baseline of what engineers do and the requirement to be technically proficient.

> "If you know what you're doing, I think that comes easy. That's technical if you actually know what you're doing."—Dermot

When describing how students learn these skills, Dermot again reveals the focus on learning from technical textbooks:

> "You know there's no substitute for actually reading the books and studying the materials."—Dermot

Finally, Kathleen when asked to describe what the term professional skills means immediately referred to discipline-specific technical skills.

> "So, I suppose I would be looking at discipline-specific skills as an engineer. You know, that you keep on top of your area, either through research, engagement with peers, that kind of thing, and attending courses. Yeah. So, discipline is always kind of my number one you know."—Kathleen

5.1.3 | Category C—Skills that enable a person to be a successful engineer

In this category, professional skills are conceptualized as skills that enable someone to become a successful engineer. Here, the focus is on the person, and success is for personal benefit, not necessarily for the benefit of the engineering company. In several instances, the skills are described as "enabling skills" that translate the foundational technical skills into something else to allow someone to become a successful engineer. These skills are described as nontechnical skills: communication, presenting an argument, and problem-solving skills. They are separate from discipline-specific technical skills.

Some interviewees specifically use the word "enable" in their definition of professional skills:

> "Professional skills are the skills that … enable our students to carry out their work as an engineer in a very professional and excellent way."—Christina

Muireann reveals the importance of developing these skills for personal benefit, not for the benefit of industry:

> "Professional skills are the skills that … well I think … that either makes or breaks you as an engineer. It's a key to success for me."—Muireann

Monica shows the distinction between discipline-specific technical skills (Category B) and enabling skills (Category C). When asked about the importance of developing these professional skills, Monica describes how they compare to discipline-specific technical skills: there is too much emphasis on technical skills, suggesting the skills they are describing are something else, that is, nontechnical skills.

> "Essential. I mean it's … I think often, there's too much emphasis on the technical."—Monica

Finally, Christina and Nichola discuss the little value of having technical skills if engineers do not have enabling skills to translate technical ideas or communicate ideas to others. Again, the focus is on the benefit to the engineer: how the engineer will be more successful with these skills.

> "If you can't share your information, if you can't go to a public hearing, if you can't stand up in front of a committee and present, it's going to be to the detriment of your own development in the profession."—Christina

> "Sometimes you can have the most intelligent brilliant engineer, but unless they're able to communicate it or unless they can work on a team-based approach, sometimes it doesn't work."—Nichola

5.1.4 | Category D—A combination of discipline-specific technical and nontechnical skills

In this category, professional skills are a mix of discipline-specific technical skills and nontechnical skills. Both are considered as important aspects of an engineer's work. This category differs from Category C (Enabling skills) in that it includes discipline-specific technical skills and nontechnical skills, whereas Category C (Enabling skills) only refers to nontechnical skills.

> "I suppose it would be made up of both soft skills and hard skills. So, I suppose the hard skills would be the technical side of things, the soft skills … would be organization, self-discipline."—Rosaleen

Finally, Mike describes professional skills as a mixture of discipline-specific technical and nontechnical skills. Mike also emphasizes the importance of being able to perform in the workplace, referring to industry benefit, and taking on responsibilities also shows the aspect of personal benefit.

> "In engineering, I suppose we would develop a sense that there'[re] some technical skills [that] are definitely in that domain. So, in electrical engineering, it could be everything from using […] AutoCAD to … you know … integrating equations or whatever. There could be specific technical skills [that] are going to enable them to take on certain responsibilities within their professional lives. And so, I think they're definitely professional skills. Then there's a whole other side of things [that] aren't maybe as specific to engineering but they are skills [that] are going to be useful in a professional workplace in the general sense. So, it could be everything from writing a grammatically correct, well-presented email, to chairing a meeting, to giving a presentation. I would see all of those things as skills [that] are potentially very useful in the workplace."—Mike

5.1.5 | Category E—Interpersonal behaviors to build successful relationships with people

Accounts associated with this category reveal the aspect of working with other people and the importance of building good working relationships in a team. Attitude toward others, empathy for others, negotiation, conflict resolution, and good listening skills are also highlighted as skills within this category. It differs from Category A (Communication Skills) as the emphasis is not only on having good communication skills but also being aware of and understanding how the skills are used. Therefore, it is described as a behavior rather than skills. Working in a team and understanding and responding to team dynamics are revealed in this category. As noted, this category is limited to local encounters with team members in a workplace scenario and does not look outward to society. Monica talks about the cognition of how to use the skills effectively by asking someone a question "in the right way," while Muireann specifically refers to working with challenging people.

> "Negotiating, communicating, listening I suppose. Asking the right question of the right person in the right way. I suppose we could generically say people skills."—Monica

> "Well, the big ones for me that probably aren't usually taught would be that spontaneous speaking and negotiation skills, conflict resolution. Those are the big things, and working on a team. So, like everything is teamwork. You know, there's always one person that you have to try and work with that you might not like to."—Muireann

Finally, Joe puts it succinctly.

> "Professional skills are the skills that lead you to having a successful relationship with your peers."—Joe

5.1.6 | Category F—Acting professionally toward people and society

This final category focuses on acting as a professional, which involves behaving professionally to other people and having the attitude, responsibility, and ethical mindset to be a professional engineer. This category is much broader than Category E (Interpersonal), as it is not just about behaving appropriately around people but includes aspects of one's character and worldview. It is not limited to local workplace encounters, as was the case in Category E. The reference to ethics, integrity, and sustainability highlights the impact of the engineer in society and the responsibility engineers have beyond their everyday engineering work life.

Acting as a professional is described in different ways: behaving respectfully to other people (Joe and Imelda), taking responsibility for one's actions (Monica and Imelda), behaving ethically (Muireann and Imelda), honesty and trustworthiness (Nichola), environmental impact of actions (Sebastian), and assuming a professional responsibility to society (Nathan). The aspect of behaving professionally toward other people was highlighted by Joe and Charlie. Joe gives an example of feeling disrespected by a student's "unprofessional" behavior. Joe goes on to describe aspects of enabling skills, communication skills, and interpersonal skills within this description.

> "I mean professional skills can be very simple things as well. And I do say to … I said it this morning—behave in a professional way. So, one student—he [sic] had a medical appointment, so he [sic] arrives an hour late. I don't think it's professional just to walk in and sit down. I think it's professional to address your line manager and say—sorry I had a medical appointment. And I encourage them to think like that, to think professionally. So, courtesy and good manners [are] very important [skills] when you're dealing with other people. You get the best from people if you respect them and […] their position. That's one thing. Other professional skills; I mean I suppose then you [are] getting towards the technical areas, but being able to present an argument [and] being able to explain something to another person […] might involve technical language. Also, I suppose having empathy for people's difficulties with things and having patience with people."—Joe

Imelda also refers to the concept of respect and gives an example of a workplace scenario where respect was not evident. This revelation was also an example in Category A (communication skills) and includes aspects of Category E (people skills). It is included here because it goes further than those categories; the focal awareness is on respectful behavior, not necessarily having the communication skills to address situations or the ability to work in a team.

> "You learn through working as well. You learn to be able to, especially whenever you're in a male-dominated industry, […] be professional and talk to people but still stand up for yourself because I've been in a room with maybe 20 men, all a lot older than I was. I'd have been what? 24 or 25. And a lot of them would have had no respect for you. I sort of developed and learned myself—where's the boundary, what to say, what not to say—but still firm enough to stand up for me."—Imelda

> "I suppose for me it would be the ethics, conducting yourself I suppose in a professional manner … I think they should know how to conduct themselves whenever they're in an environment."—Imelda

Examples of when Imelda used professional skills in the workplace follows:

> "… conducting myself appropriately. Dressing appropriately. The manner in [which] I speak to the students … In the lab situation, I will try and always bend down to their level in the lab. I'll never talk over someone in the middle of the lab, I'll always go down on my hunkers [and] look at the screen with them because then they're on [the same level] with me. So, I would do all of that kind of stuff … Then, in industry, I suppose you had lots of it. It's the same thing; you're reporting to a manager. At the end of the day, he's [sic] your boss. You have to speak to him [sic] appropriately. Turn up appropriately. Come into work appropriately. All of that really."—Imelda

Nathan also reveals how in practice engineers must be mindful of their behaviors and moderate them per the situation, which is an example of behaving professionally.

> "You then kind of, from a professionalism point of view, have to understand that in practice you have to be a professional, irrespective of whether the client is treating you well or not. When you come up with a problem on a site with a project, how do you professionally deal with that [and] not lose [your] rag? And what [is] our responsibility […] then."—Nathan

The revelation that to behave professionally includes consideration of ethics and working with integrity reveals the broader conception that includes the character of the engineer. Muireann discusses behaving professionally and adds the aspect of ethics and working with integrity, a view shared by Nichola.

> "I think whatever they write, their e-mails that they write, the documentation that they put together, you know, that it is professional. So then, I suppose I don't touch enough on it, but I really think on the ethics of … just working with integrity. You know, so many of them ask me like 'Sure, like how do you know, can I not just make up that data?' 'Absolutely you can'. You know. So, I do introduce that discussion. Now I do think there should be an awful lot more than that. It's very very hard to bring it in because it's so individual I suppose."—Muireann

> "Professional skills to me means honesty, trustability, good communication skills, integrity. Things like that, sometimes things that can't be learned from a book. To realize the importance of co-workers and colleagues, to listen to everyone's opinions."—Nichola

Nathan and Sebastian describe professional skills as including several key aspects: having the core technical skills to work responsibly (Category B), how engineers interact with other people and clients (Category E), and being aware of the impact of an engineer's work upon the environment and society in general (Category F).

> "So, you need to be able to tackle problems you haven't seen before and poorly defined problems. Most of the time you don't have enough information and so I think, to be a good professional engineer, you need to have a very solid [foundation] in the principles of the profession, so that's maths, physics, and those types of subjects. I think that's really important as your core. I think also, a lot of the time as an engineer, what you're doing is you're on the phone … you're meeting people and you need to get across to someone who might not have your background [or know] what's important and why it's important. So communication is definitely really really big … And then there'[re] other things around ethics and maybe sustainability and things like that which would be good for an engineer to have in their mind as they go about their professional job."—Sebastian

While it has been interpreted that utterances that mentioned the importance of acting ethically and with integrity show an awareness of how engineers interact with society, Nathan provides the quote which forms the pinnacle of this category: specifically recognizing the impact on society.

> "[Therefore], professionalism is the technical knowledge that you bring into industry, but it's also the way you manage and run [a] business, the way that you have a professional responsibility to your clients [and] society, and [the way you] contribute back."—Nathan

In summary, the data revealed six categories of description. Table 2 shows a tabular form of the outcome space for conceptions of professional skills that details the aspects of the themes of expanding awareness (in the first column on the left) relative to each of the categories of description.

5.2 | Hierarchical structure—Conceptions of professional skills

The first step in creating an outcome space is to reveal the categories of description. However, a phenomenographic study considers that there are logical relations between the categories of description. While the logical relations can be determined by considering the differences in the themes of expanding awareness, there is also value in making the outcome space hierarchical, particularly if the intention is for the study to be used in an educational setting. Presenting an outcome space hierarchically allows readers to reflect on their position on the hierarchy and to consider more complete ways of understanding a phenomenon.

It is important to state some assumptions to differentiate conceptions of professional skills from categories of description at the beginning of this section to prepare the reader for the discussion on how the hierarchical structure was defined. Thus, so far, this study has described the six categories of description revealed in the data, that is,

TABLE 2 Outcome space for conceptions of professional skills (Tabular Form).

Variation	Category A - Communication	Category B - Technical	Category C - Enabling	Category D - Combination	Category E - Interpersonal	Category F - Acting professionally
Purpose	To *communicate* verbally and in written form and to make your voice heard	To have discipline-specific technical skills you can *use as an engineer*	To enable a person *to be successful* as an engineer	To have a mix of technical and other skills *to function* as an engineer	To *work with other people*, to have good relationships with your peers	To *act professionally* toward people and society
Benefit	Personal benefit	Industry benefit	Personal benefit	Personal and industry benefits	Personal and industry benefits	Personal, industry, and societal benefits
Type	Non-discipline-specific	Discipline-specific technical	Non-discipline-specific	Discipline-specific and non-discipline-specific	Non-discipline-specific	Non-discipline-specific
	SKILLS	SKILLS	SKILLS	SKILLS	BEHAVIOR	SKILLS and BEHAVIOR
	Verbal and written communication	Technical discipline-specific skills	Communication, present an argument, solve problems	Combination of skills	Attitude toward others. Respect and courtesy	Attitude, responsibility ethics, and integrity

professional skills can be described using six categories of description. However, the term "conceptions of professional skills" is different from "categories of description." We use the term "conceptions of professional skills" to mean the qualitatively different ways of experiencing professional skills, a term appropriate to use in a phenomenographic study. In essence, we investigated faculty's experiences of professional skills (asking them to describe different aspects of their engagement with the phenomenon of professional skills) in order to describe the qualitatively different ways that faculty conceptualizes professional skills.

A conception of professional skills may include one or more categories of description (Åkerlind, 2005a). Hence, this study proposes that individuals will have a conception of professional skills that may include one or several of the six categories of description revealed in this study. For example, a participant may have revealed that they believe professional skills to be Categories A (Communication), B (Technical), and C (Enabling), as in some of the noted utterances. The hierarchy was developed by reviewing the variation in the themes of expanding awareness indicated in Table 2 and the different categories of description revealed by each participant. Notably, not every participant revealed the same combinations nor are we suggesting that higher level categories (e.g., Category F) always include lower level categories. The diagrams merely assist in visualizing the logical relations revealed in the outcome space. At this point, we should also explain that we do not intend to create outcomes that describe conceptions as a whole, we are instead attesting that faculty will have differing conceptions and these conceptions are made up of the categories of description described in the outcome space, some of which are hierarchically more superior than others, meaning higher level categories of description show a more complete way of understanding. Further we provide additional insight into how one can transition from one category of description to another in Table 3.

One of the key findings is the acknowledgment among faculty on the importance of behaviors, that is, professional skills are not limited to skills alone but involve behaving in a particular way. Furthermore, the aspect of "benefit" (i.e., who benefits from the development of the skills) is another important finding. Therefore, the diagrams are drawn relative to two axes to show how each category of description differs regarding the type of skills and to whose benefit. Figure 2 employs the themes of expanding awareness "Type" and "Benefit" to show the relationship between each category within the hierarchical diagram. Figure 2 also indicates thresholds where a change in perspective is required, which is detailed further in Table 3.

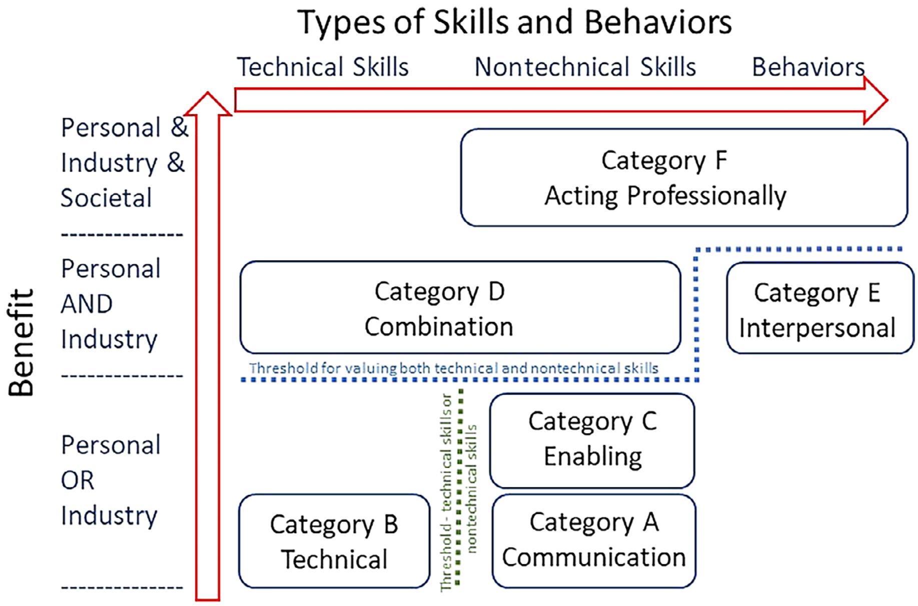

FIGURE 2 Outcome space "conceptions of professional skills" in pictorial form.

The findings indicate that there are logically related and hierarchical categories that describe how professional skills are experienced by participants. However, it is also useful to explicitly describe a developmental path that enables learners to become aware of a more complete way of understanding professional skills. To this end, we sought to understand the relationships between the categories and Table 3 highlights the key indicators of qualitative differences. As a precursor, Category A (Communication) and Category B (Technical) are distinct from each other. Category A (Communication) focuses on non-discipline-specific skills such as verbal and written communication that benefit the individual, while Category B (Technical) is concerned with discipline-specific technical skills that benefit industry. The difference between these two categories is best described as a threshold concept, which determines whether professional skills are discipline-specific technical skills or more generic skills that are independent of the discipline, as illustrated in Figure 2. Table 3 illustrates the hierarchy of further conceptions that explicate how one can transition to a more complete understanding of professional skills as they move through the hierarchy. By understanding the relationships between the categories, educators can focus on developing their conceptions in a structured and systematic way, which can help them become more effective in their professional roles.

Having described the patterns of variation between categories, it is also worthy to note dimensions of variation within categories. Two dimensions of variation were found within categories but did not distinguish between them, and therefore were not selected as themes of expanding awareness between categories. These dimensions relate to where and how faculty learned their own professional skills. Three aspects were revealed in terms of where faculty learned their professional skills: in university, in the workplace, and in life. A limited number of participants mentioned learning skills in university, and these skills were not solely discipline specific, but included non-discipline-specific skills too. Many respondents indicated that they had developed their professional skills in the workplace, again this covered participants with a range of conceptions on what professional skills entail. The final variation was that faculty discussed learning their professional skills through life experiences, separate from their work as an engineer. This is illustrated in the quote from Imelda who discusses how they learned to be respectful from an early age when asked about where they developed their professional skills.

> "… growing up, parental influence. You didn't speak until you were spoken to as such. And if someone was in the house, you had manners … So a lot of it would have come from what I developed at home …. I think it was just [my] upbringing."—Imelda

The second dimension of variation, which was found within categories but did not distinguish between them, relates to how faculty acquire their own professional skills. Four aspects were revealed in this analysis: observing and reflecting, participating in a work environment, including mentoring or feedback from others, and life experiences. Although some of these approaches were mentioned in different categories, they were not critical aspects of variation. In other

TABLE 3 Summary of transitions between categories.

Transition	Description of qualitative differences between ways of experiencing
Communication → Enabling	This difference is characterized by a transition into awareness that good (non-discipline specific) skills can be of benefit to the person and not necessarily just for industry. They are the skills to "enable" an engineer to be successful in their own personal development and career. The transition is to accept the critical importance of these non-discipline-specific skills in succeeding as an engineer.
Technical → Combination and Enabling → Combination	A change occurs in this transition by crossing a threshold that recognizes the value of both discipline-specific and non-discipline-specific skills. Now, both types of skills are recognized as critical to function as an engineer and have both personal and industry benefit.
Enabling → Interpersonal	The transition from moving from an enabling category to interpersonal category is to move from an internal facing perspective (on an individual level) to an outward facing perspective, that of the importance of working with others. Engineers need to be able to work in teams in industry, and thus appreciating the importance of behaviors such as attitudes, respect, and courtesy are the key distinctions in this transition.
Combination → Acting professionally	The combination category already recognizes the importance of both discipline-specific and non-discipline-specific skills, but the transition to acting professionally is to place a focus on the importance of an engineer's actions on other people and also on society in regard to their professional work. This includes both the use of the skills they have developed, but also their behavior toward others and their attitude and worldview toward society and the implications of their work.
Interpersonal → Acting professionally	A change occurs here in crossing the threshold that values both discipline-specific and non-discipline-specific skills. It is recognized that although interpersonal skills are critically important, an engineer also needs a sound foundation in discipline-specific technical skills. Further, the transition to acting professionally includes aspects of one's character and worldview, it is not limited to developing skills, but reflects behavioral traits. Fundamentally, engineers need to be able to design artifacts safely by having excellent discipline-specific skills, coupled with excellent interpersonal skills to work with others to deliver projects and do so in a way that showcases responsible attitudes, ethics, and integrity toward people and society.

words, a specific way of learning did not align with a particular category of description. Each aspect is illustrated by a quote beginning with Imelda who describes the experience of observing behavior when asked about how they learned their professional skills:

> "I suppose probably from observing other people. Whenever you start going to big meetings like that and you see what's going on and you know when you see someone that says something that's ... really just inappropriate and you think .... I never want to say something like that, you know it just looks so unprofessional and just rude. So, I probably would have observed at the start."—Imelda

Nichola also clearly describes how they learned their professional skills in the workplace through working closely and being mentoring by colleagues:

> "I suppose through mentoring, especially by very good bosses that I had."—Nichola

Muireann's statement highlights the impact of life experiences, specifically acting classes and involvement in social clubs, on their development of professional skills.

> "In other areas, I know for myself, I did a lot of acting when I was younger. Definitely, that would have given me a little more confidence ... and I was involved in a lot of social clubs and different things like that."—Muireann

These findings raise an interesting issue regarding the development of professional skills that may not solely be the responsibility of universities. While universities play a crucial role in providing academic education, it is important to recognize that professional skills encompass a broader set of competencies that extend beyond the classroom.

Furthermore, additional research is warranted on how faculty can be supported and assisted in providing opportunities for engineering students to develop professional skills, particularly in relation to observing and reflecting and mentoring and feedback.

6 | DISCUSSION AND CONCLUSION

The findings bridge the gap in the current literature and provide a fundamental prerequisite for transforming academic practice. They challenge existing assumptions and offer new perspectives on how professional skills should be understood. Adams and Felder (2008) describe challenges and new roles for engineering educators to support their engagement in professional development. The first is to become an educational philosopher and provocateur, someone who engages in dialogue about the skills and values engineering graduates should possess and to advocate for new perspectives that challenge traditional views. The outcome space created as part of this study can be used as a prompt to begin the conversations around the aspect of professional skills requirements. Further, it can be used to engage faculty by allowing them to reflect on their conceptions of what professional skills are and to be exposed to a more complete appreciation of what professional skills could entail. Becoming a scholarly teacher and a reflective practitioner is another role advocated by Adams and Felder (2008) and the pictorial outcome space can be used to identify and then reflect on current conceptions, and to then imagine links between the research findings and teaching practice (Adams & Felder, 2008).

As a secondary step, the themes of expanding awareness and the learning pathways described in Table 3 can form a basis to work on expanding their original conceptions. For example, someone who initially aligns with Category A (Communication) and considers that good communication is only for the benefit of the individual can be prompted to think about the industrial and societal benefits of good communication. Further, the transitionary steps described in Table 3 can be complemented with new pedagogical approaches in order that the more complete understanding of what professional skills entails is translated to the classroom. In particular, the thresholds that were identified showcase that it is important that educators value both technical and nontechnical skills, hence professional development courses should be offered to address both of these aspects. Further, hiring and promotional practices, which value both of these types of skills in faculty, could bring more attention to this issue as engineering educators are often hired for technical expertise and not for their own professional skills (Miller, 2015; Pons, 2016). There is also a recognition that transformation of engineering education requires more emphasis on the impact of engineering work on people and society (Beagon et al., 2022), and hence professional development courses in issues such as sustainability and ethics education could provide a basis for supporting the transition to the highest category of description, Category F (acting professionally).

A few other significant aspects of the outcome space merit further discussion and add to our knowledge in this area. The first is the acknowledgment of Category F (acting professionally) to conceptualize professional skills and the emphasis on behaviors in addition to skills. This finding adds new insight to the literature for suggesting that future research in learning and teaching approaches should focus on behaviors rather than skills. Many prior studies probe skills or competences (Colman & Willmott, 2016; Husain et al., 2010; Kövesi & Csizmadia, 2016; Le & Tam, 2008; Male et al., 2011; Nair et al., 2009; Passow, 2012), and several acknowledge the importance of some behaviors but are often limited to the concept of ethics. For example, Passow (2012, p. 99) considers that the ABET competencies offer an "appreciation for the ethical values of being a professional" and "understanding of professionals and ethical responsibility." Similarly, Le and Tam (2008, p. 360) use the Engineers Australia competences, which refer to sustainable development and "understanding of professional and ethical responsibility and committing to them." One study goes beyond the ethical considerations and recognizes traits such as "being committed to doing your best," "acting with exemplary ethical standards," and "actively promoting diversity within your organisation" (Male et al., 2011, pp. 154–155). Richard Miller, former president of Olin College, acknowledged the need for "a set of attitudes, behaviors, and motivations," what they call a mindset; however, they also raise concerns regarding whether an educational program can teach the required mindset (Miller, 2015, p. 11). This finding, which highlights behaviors, clearly aligns with the call for transformation toward a more humanistic approach to engineering (Sorby et al., 2021) and the importance of being careful about what terms we use and their impact on teaching approaches and student interpretations of what is important (Berdanier, 2021). The findings highlight behavior as a key requirement of what it means to be a professional engineer. Even so, Miller's (2015) views on whether faculty are adequately trained to teach these skills raise concerns about how to teach "acting professionally." Perhaps, we must acknowledge the professional behavior (or lack thereof) of our colleagues in specific situations, something Berdanier (2021) acknowledges can be challenging to call out.

The second aspect of interest in the outcome space is the themes of expanding awareness. While previous studies recognize the type of skills (Barrie, 2007), the themes of purpose and benefit add a new perspective. They shed new light on the discourse surrounding professional skills and can help faculty reflect on their assumptions about the purpose of developing skills. The purpose can be described as inward facing, where the focus is on the engineer, or outward facing, where the focus is on interactions with others or society. This finding may encourage faculty to engage in dialogue with their peers and engineering students, bringing a new understanding to the purpose of developing skills, a key recommendation of Chan and Luk (2022). Some faculty members believe professional skills must only satisfy industry requirements. Others see the value in developing professional skills in students to be successful in life. However, the most developed conception, one with Category F (acting professionally), includes an acknowledgment that there will be personal, industrial, and societal benefits from engineers developing such skills. Regarding the identification of the specific categories, it is important to compare them with prior work. Identifying professional skills as technical skills only (Category B) was a surprising finding because, while most recent studies acknowledge that technical and nontechnical skills are required to be an engineer, professional skills are generally considered the "nontechnical skills" part of the equation. However, it reveals that some faculty hold that technical skills are the most valued type of professional skills for engineers, a finding that accords with Chan and Luk (2022). Further, it is interesting to note that Category B (technical skills) is associated with benefitting industry only, while the broader impact on society is overlooked. Indeed, it can be argued that strong technical skills can have a profound impact on society as they are crucial for engineers to create innovative solutions that address societal challenges. However, the aspect of society is only brought to the fore in Category F (acting professionally), which encompasses aspects of both technical skills and nontechnical skills.

Conversely, it was also interesting to note that technical skills (Category B) were also revealed as a component of the conception of professional skills. There is usually a distinction between technical and professional skills, creating a false dichotomy as if they are two separate things, which must be taught separately. Furthermore, there is a struggle between which one is taught at the expense of the other (Chan & Luk, 2022). The findings are quite revealing: some faculty do not necessarily see them as two separate things. This finding is key for the engineering education community and policy-makers. It discourages the false dichotomy, as per Berdanier (2021), who calls for mindfulness of seeing professional skills (soft skills) as "nonengineering" skills.

This study also revealed gendered differences in the conceptions of professional skills. The analysis indicated that women were more inclined to conceptualize professional skills as nontechnical skills and behaviors than to include technical skills as a component. This contrasted with men, who were more likely to include technical skills as a component of professional skills. It is important to note that the sample size is too small to draw definitive conclusions, but this observation suggests a significant interaction between gender and conception, which warrants further exploration.

Additionally, it is interesting to highlight the differences in verbalized responses from women and men. Women mentioned aspects such as the tone of their voice, their accent, or the dress code. This prompts consideration of whether the identified differences by each gender points to identity theory and raises questions about potential relationships between intersecting aspects of identity. For instance, do the intersecting identities of women as both engineers and women influence their conceptions of professional skills? What constructs within their identity and background experiences provide them with unique perspectives? The literature has also highlighted how marginalized groups adopt the dominant culture through changes in their language, behavior, and appearance including their dress code (Chinn, 1999; Ong et al., 2020), all of which were also revealed by women in this study. Pawley (2019) carried out a study among undergraduate engineering students, focused on women and men of color and White women, to explore how gender and race are built into engineering education in relation to institutional structures using the theory of ruling relations. Davis et al. (2023) investigated the experiences of marginalized students regarding departmental climate, which included their interactions with faculty and showed the impact of faculty behaviors on students. Faculty interactions were also recognized as impactful in terms of students' satisfaction with their course (Amelink & Creamer, 2010). The findings raise intriguing questions and additional research into intersecting aspects of identity of engineering faculty could help inform us both in regard to attracting and retaining diverse teaching staff (Sorby et al., 2021), but also in writing appropriate learning and teaching resources, which are more diverse and inclusive (Knight et al., 2012).

Initially, we described that transformation of engineering education would only be successful if faculty align with the values that are needed for the transformation effort. Taking this one step further, exposing faculty to a broader understanding of professional skills, including the societal benefits and the significance of behaviors, can be a catalyst for action in the classroom. When faculty members recognize the importance of these aspects, they are more likely to integrate them into their interactions with students and the hidden curriculum—the implicit lessons and values that students absorb in the academic environment. The next step is to then consider the different pedagogies that would be appropriate to expose students to the differing aspects of professional skills they will need. It is essential for faculty to receive professional development that equips them with the knowledge and skills necessary to effectively implement these pedagogical approaches (Adams & Felder, 2008). By addressing any gaps in faculty knowledge and promoting their growth as educators, the implementation of these initiatives can be more successful.

6.1 | Implications for engineering education

The outcome space for conceptions of professional skills can be used in two ways. First, for a top-down approach, before setting standards and guiding policies in HEIs on professional skills or creating accreditation criteria to influence curriculum design, a multilevel policy appealing to all the different ways of understanding is necessary. Therefore, any policy changes regarding developing professional skills in engineering students must recognize that some would like to concentrate on the lowest level conception, such as communication skills, while others may wish to focus on technical skills only. Furthermore, some may have a more complete conception of professional skills. Policies should recognize the multifaceted way of understanding to encourage all faculty to engage in the process.

This study describes qualitatively different ways that faculty understand the concept of professional skills. Thus, it notes the fact that there is no common understanding, suggesting that some faculty are unlikely to be receptive to calls for transformation of engineering education by implementing more professional skills in engineering curricula (Barrie, 2006, 2007; Chan & Luk, 2022). It also furnishes insight into some of the reasons that may underlie the lack of educational transformation in this area. The findings may help in the context of university accreditation bodies and policy development, given the increasing demands for universities to produce well-rounded graduates.

Second, for a bottom-up approach, faculty interested in developing their learning and teaching capability need resources and outputs aimed at appreciating how their conceptions or approaches are limited (Chan & Luk, 2022). The outcome spaces (in pictorial form) and the transitionary steps can be used as such a resource, a way to stress, not skills acquisition per se, but growth in understanding professional skills in more comprehensive ways. In particular, it is important to highlight acting professionally, which is centered around how we interact with people. Hence, faculty must realize that their attitudes and behaviors to students and colleagues alike can influence students' perceptions of the value placed on these aspects (Sorby et al., 2021), what Adams and Felder (2008) describe as social learning.

Finally, the outcome space can be used to identify professional development targets for faculty to address any gaps in their knowledge on how best to deliver initiatives to expose students to opportunities to develop the skills, attitudes, and behaviors described. By identifying and implementing appropriate pedagogical approaches, faculty members can promote the integration of professional skills into the classroom and create an environment that nurtures the holistic development of engineering students. It is through their actions and interactions with students that the hidden curriculum can reinforce the broader understanding of professional skills and their societal impact.

6.2 | Further work

Despite answering the research question, the findings highlight other important aspects that warrant further research. Future studies can consider a comparative study outside of the European Union to determine whether the same variation in conceptions exists, a study to ascertain the percentage of learning outcomes in engineering programs that reflect different conceptions of professional skills, and a study with engineering students and engineering employers to compare them and highlight gaps.

This study also revealed gendered differences in the conceptions of professional skills, and there is scope for a study on gendered differences among engineering educators regarding what they value in terms of professional skills, as well as more broadly in relation to gender, race, or other aspects of identity and how these factors impact faculty's perceptions in this context.

The findings can be used to draw attention to this phenomenon among educators, evaluate curricula, and devise new teaching approaches. For instance, mapping exercises could assess the extent to which each aspect of professional skills is incorporated within engineering programs (Albareda-Tiana et al., 2020; Crean et al., 2021; Segalàs Coral & Sánchez Carracedo, 2020). Although the research question addressed in this study pertains to faculty conceptions of professional skills, the ultimate goal is to contribute to the transformation of engineering education. Therefore, the initial step was to gain a better understanding of faculty, which can then inform further work to determine appropriate interventions or teaching pedagogies to support faculty in providing students with opportunities to develop these professional skills.

For example, active learning strategies, which promote student engagement and experiential learning to mirror real-life work experience and team projects, can help develop communication, technical, and enabling skills. Working on team projects with peer feedback can also be used to enhance interpersonal skills, and the integration of ethics and social responsibility into project work can work toward exposing students to responsible engineering practices. It is important to recognize that faculty serve as role models to students, whether they realize it or not. Indeed, role-playing may be a fitting pedagogy for exposing students to Category F (acting professionally), particularly when they are working with an industry partner (Andersson & Andersson, 2010). As a further resource, examples of learning outcomes regarding professional skills and specific case studies on how behavioral skills can be taught would be welcomed.

6.3 | Conclusion

This study revealed several key findings that expand on the body of knowledge surrounding professional skills in an engineering education context. First, the study created a new outcome space (conceptions of professional skills), which describes the qualitatively different ways faculty conceptualize professional skills. This study is contextual to faculty staff teaching engineering programs in Ireland.

Second, six categories of description to describe conceptions of professional skills were identified: Category A (communication), Category B (technical), Category C (enabling), Category D (combination), Category E (interpersonal), and Category F (acting professionally). The categories are hierarchical to show comprehensive ways of understanding what professional skills entail. The findings show some alignment with prior studies, but the most surprising finding was Category F (acting professionally), which includes skills and behaviors. This finding sheds light on the importance of faculty understanding that they are role models to students through their actions and behaviors, regardless of whether they are aware of it. Assessment techniques to assess behaviors would provide a useful resource for faculty. It is also interesting to note that there are some faculty who consider technical skills as a subset of professional skills. It suggests a false dichotomy between technical and professional skills, where one could be taught at the expense of the other; this study suggests that this likelihood is not the case for all conceptions. Hence, the findings allow for addressing this concern by including technical skills as a critical component part of professional skills. Three themes of expanding awareness differentiate the six categories of description of professional skills: purpose, benefit, and type. Each category is described by the purpose of, who benefits from (personal, industrial, or societal benefit), and the type of (technical skills, nontechnical skills, and behaviors) skills development. The themes can also be used to engage faculty and students in a dialogue about professional skills and their importance.

It is essential for faculty to receive professional development that equips them with the knowledge and skills necessary to contribute to an effective educational program for engineering students. Faculty development programs can focus on areas such as reflecting on their conceptions of professional skills and all that they entail, considering how they can undertake professional development in order to transition to a more complete and comprehensive understanding and finally designing appropriate learning experiences for students in order that they can develop the required skills. This study makes a valuable contribution by presenting an outcome space that can be utilized to identify gaps, which can then be used as a foundation for identifying areas where personal development and growth are needed. By combining targeted faculty development with appropriate pedagogies, engineering programs can provide students with a well-rounded education that nurtures their professional skills. This holistic approach prepares students to become competent engineers who can thrive in their careers and make positive contributions to society.

By analyzing the conceptions of professional skills among faculty, this study offers insights into the areas where improvements can be made, allowing for targeted interventions and personal development initiatives. This information can be used to create tailored programs and resources that address the specific needs identified, thus supporting and enhancing the personal development of faculty members. This, in turn, enables them to effectively contribute to the transformation of engineering education. This approach ensures that faculty have the necessary skills and competencies to provide quality education and mentorship to engineering students, ultimately enhancing the overall learning experience and preparing students for their professional careers in an ever-changing society.

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APPENDIX A

DETAILED DESCRIPTION OF SURVEY AND SELECTION OF PARTICIPANTS

Online survey—Selection of interviewees

A phenomenographic study relies on gaining a wide selection of participants to maximize variation. Thus, we created an online survey that was circulated to the entire data pool of faculty teaching engineering programs in Ireland ($n = 942 \pm 60$) and gained a response rate of $n = 321$ (34%). Initial data cleansing reduced it to 309. Finally, 273 (29%) respondents answered all questions, from which pool interviewees were chosen. The survey collected data on gender, age, higher education institutions, industrial and academic experience, and qualifications. We asked respondents to indicate opinions on some provocative statements and the importance of specific skills. The questions aimed to create a mechanism by which we can choose respondents who are atypical to maximize variation within the interview pool.

We also considered that gender was an important consideration, noting that the cohort of faculty teaching engineering programs in Ireland is predominantly men, at approximately 88% (Beagon & Bowe, 2019). However, in a phenomenographic study, the aim is not to provide a representative outcome of the group, but to provide an outcome that shows maximum variation. Per Reed's (2006) argument, gender is an artificial distinction in a phenomenographic study; however, we also considered how emotion can affect women's experiences relative to men (Campbell & Wasco, 2000; Hazel et al., 1997) and aimed for a 50% gender split.

The design or the general findings of the survey are not included in this paper to stick to the core of the research work; however, a summary of how interviewees were selected is presented here to show the robustness of the selection process. For the survey design, including the list of professional skills used, analysis, and results, see Beagon and Bowe (2019) and Beagon (2021).

Twenty interviews were originally planned for this phenomenographic study; hence, approximately 30 respondents were selected as first-choice or backup candidates. The selection criteria were prioritized based on the research questions and the type of relationships we wished to investigate. The determination priority was as follows:

1. Gender.
2. Industrial experience.
3. Approaches to teaching inventory results (Trigwell & Prosser, 2004).
4. Academic and educational qualifications.
5. Academic experience.
6. Engineers Ireland activity.
7. Outlier opinions on provocative statements.
8. Outlier opinions on the importance of relevant skills.
9. Age.
10. Institution.

Survey respondents were invited to provide contact email addresses should they wish to be considered for an interview. In total, 162 (of 273) respondents provided contact details, which provided the original pool for selection. Through each selection step, every respondent of interest was tagged relative to the priorities (Px). This system was created within an excel spreadsheet (Figure A1). Upon completion of all 19 tagging steps described below, the number of tags allocated to each respondent was recorded, which allowed for a ranking system of potential interviewees to be drawn up. For example, 10 separate priority tags were allocated to one respondent; thus, they became top of the interview list, with a respondent with nine tags in second place. The potential interviewee list was then back-checked to ensure there were minimum respondents within each category of interest.

Gender

The first priority regards gender. As only 22% of the respondents were women, a 50% split by gender was considered worthwhile. Reed (2006) argues that the researcher must not be swayed by gender or cultural inclusivity, which are in a phenomenographic sense, artificial distinctions. However, Hazel et al. (1997) argue for the opposite: emotional responses are important and differ between the genders. Therefore, we advocated for a purposive sample including gender as a basis for variation for a clearer picture. This aspect became even more important based on the results of the survey, which showed gender bias in some of the responses. Ten of the remaining 162 respondents selected "other or prefer not to say," which was not used as a basis for selection at this point. Even so, the final list was reviewed to ensure at least one interviewee is included in this gender choice. Thirty-six of the 162 respondents were female and were tagged as Priority 1 (P1).

Respondent ID	P1 (Female)	P2 (No Industrial Experien	P3 (>20 yrs industr	P4 (Worked with gradua	P5 (Outlier ATI results)	P6 (PhD)
6546217763			P3 (>20 yrs industry)	P4 (Worked with graduates)	P5 (Outlier CCSF)	
6487080580	P1 (Female)				P5 (Outlier ITTF and CCSF)	
6551935959	P1 (Female)			P4 (Worked with graduates)	P5 (Outlier CCSF)	
6545611312			P3 (>20 yrs industry)	P4 (Worked with graduates)		
6536058873			P3 (>20 yrs industry)	P4 (Worked with graduates)		
6532813430				P4 (Worked with graduates)	P5 (Outlier CCSF)	
6530132268	P1 (Female)	P2 (No Industrial Experience)			P5 (Outlier ITTF)	
6528333966	P1 (Female)			P4 (Worked with graduates)		
6508432726	P1 (Female)	P2 (No Industrial Experience)				P6 (PhD or DEd)
6508305707			P3 (>20 yrs industry)	P4 (Worked with graduates)	P5 (Outlier CCSF)	P6 (PhD or DEd)
6501015956			P3 (>20 yrs industry)	P4 (Worked with graduates)	P5 (Outlier CCSF)	P6 (PhD or DEd)
6500542113	P1 (Female)			P4 (Worked with graduates)		P6 (PhD or DEd)

FIGURE A1 Spreadsheet extract on how each respondent was tagged relative to priorities.

It is important to note at this point that the survey question was entitled “Gender” albeit the options given referred to biological sex (Male/Female/Other/Prefer not to say). Upon review, it is noted that it would be more appropriate to have provided terms such as man, woman, or other/prefer not to say for this question in line with good practice and the principles of bias-free language. However, the results are presented as collected to maintain authenticity of the data.

Industrial experience

We considered that industrial experience and the length of time and interactions with graduates were important in this study. Three priority items were included in this category: no industrial experience (P2); greater than 20 years of experience (P3); and recruited, trained, or worked with graduates (P4). Each person who fell into one of these categories received a priority tag.

Approaches to teaching inventory results

The Approaches to Teaching Inventory (ATIs) are designed to identify, within a certain context, whether a faculty member uses a teacher-centered (ITTF) or student-centered approach (CCSF) (Trigwell & Prosser, 2004). We focused on how this approach regards teaching professional skills; therefore, the respondents who indicated extreme alliances with each of these approaches were identified in this priority list. Further, to select respondents for the interview, the extreme or outlier CCSF and ITTF scores were considered with thresholds of 20, 26, 28, and 30, with a maximum score of 32. Table A1 presents the number of respondents in each threshold.

Academic and educational qualifications

We focused on the effect a research career can have on faculty conceptions; thus, Priorities P6 and P7 were used to identify those with a PhD or EdD and those without. Although it means each respondent scored either P6 or P7, it allowed for checking to make sure there was an even spread of those with and without. It is also the case for the following categories. Many respondents had educational qualifications, such as postgraduate diplomas in teaching. Thus, for maximum variation, it was important to have a mix of both. Hence, Priority P8 was allocated to those with educational qualifications and Priority P9 to those without.

Academic experience

There was a range of academic experience from under 5 years to over 21 years; these extremities were used within this priority as P10 and P11. Other lengths of academic experience should also be included within the overall sample, which was checked within the final list. We were also interested in obtaining contrasting views of those mainly lecturing (P12) and those who consider themselves researchers (P13). Both of these selections were allocated priorities.

TABLE A1 Threshold analysis of ITTF and CCSF scores.

Threshold value	Number of respondents who exceeded the ITTF scale threshold	Number of respondents who exceeded the CCSF scale threshold
Greater than 20	60	93
Greater than 26	**6**	**22**
Greater than 28	2	10
Greater than 30	1	2

Note: A threshold value of 26 was used out of a maximum score of 32. All those with Conceptual Change/Student-Focused (CCSF) or Information Transmission/Teacher-focused (ITTF) values greater than 26 were tagged as a Priority P5. For more information on how the ATI was used in the survey, please refer to Beagon and Bowe (2019) and Beagon (2021).

Engineers Ireland activity

Chartered or fellowship membership of Engineers Ireland suggests time spent in industry and a commitment to keeping abreast of new challenges within engineering. Thus, Priority P14 was allocated to chartered and fellow members of Engineers Ireland, and P15 to nonmembers. Contribution to an Engineers Ireland accreditation means that respondents are aware of the program outcome requirements of the accreditation process, which required faculty to include professional skills such as communication and teamwork in their modules. Hence, those with an accreditation received Priority P16, and those who were not received P17.

Outlier opinions on provocative statements

Provocative statements were used to gauge the range of opinions of all respondents. In this section, only outliers were identified (i.e., those who did not agree with the majority opinion). Outliers were determined by considering the average score and selecting those whose opinions differed the most from this view. Table A2 presents the average score for each statement. As most statements resulted in an overall score between 0 and 1, only respondents who selected "Strongly Disagree" (−5) or "Strongly Agree (+5)" were tagged, (P18). Regarding the statement on global outlook, the average score was 2.21; hence, in this case, an outlier was considered someone who scored −3 or less in this category (i.e., those who disagreed with the majority opinion). Table A2 summarizes the outlier scores.

Outlier opinions on the importance of relevant skills

A similar tagging system was undertaken for respondents who were outliers in the important skills (P19) list. Each extremity was identified, considering the average score for the overall sample (Table A3).

Sample selection

The respondent's tags were added and ranked. One respondent was allocated 10 tags, six were tagged 9 times, and 26 respondents were tagged 8 times. The sample was therefore condensed to a pool of 33 potential interviewees. The next step was to check whether all variables had been included in the sample and the list of 33 interviewees. Table A4 indicates the numbers allocated to each attribute.

It was determined that the 33 academics selected within the pool provided a varied range of academic and industry backgrounds along with outlier scores on the ATI, the provocative statement, and the skills list. The top selected interviewees were then determined by considering location and ease of access for the interview, and they were contacted first. Table A5 summarizes the key demographics of each interviewee.

TABLE A2 Outlier scores considered for each statement.

Statement	Mean score	Outlier score considered
Candidates with first class honors are always the best prepared for the industry	−0.16	−5 or +5
Excellent technical skills are more important than excellent professional skills	−0.22	−5 or +5
The engineering curriculum has the capacity for more emphasis to be placed on teaching professional skills	0.41	−5 or +5
It is the employer's responsibility to teach professional skills	−0.43	−5 or +5
It is the academic's responsibility to teach professional skills	0.57	−5 or +5
Engineering graduates in Ireland should have a global outlook	2.21	−5, −4 or −3

TABLE A3 Extremities used to identify outliers with opinions on skills requirements.

Skill	Mean score out of 4	Extremity identified
Foreign language skills (communicate in a second language)	1.5	Score of 0 (not important) or 4 (essential)
General knowledge (current affairs, politics)	2.0	Score of 0 (not important) or 4 (essential)
Business acumen (financial and budgeting/cost control awareness)	2.3	Score of 0
Global outlook (international and intercultural skills)	2.5	Score of 0
Leadership (responsibility, leading and directing teams)	2.6	Score of 0
Risk management (identify and reduce risk)	2.7	Score of 0
Research skills (research a project or product)	2.9	Score of 0
Health and safety (within a specific industry)	3.0	Score of 0
Project management (time management, planning skills)	3.1	Score of 0
Excellence in technical skills (excellent technical capability)	3.2	Score of 0
Character and interpersonal skills (integrity, social skills, work ethic)	3.3	Score of 0
Teamwork and collaboration skills (working with diverse people)	3.5	Score of 0
Self-direction (initiative, independent work, continuous learning)	3.5	Score of 0
Practical focus (apply theory to real-life problems)	3.5	Score of 0
Critical thinking (evaluate all aspects of problems and solutions)	3.6	Score of 0
Communication (written, oral, listening skills)	3.6	Score of 0
Problem-solving (visualize and present practical solutions)	3.7	Score of 0

TABLE A4 Mapping of attributes in chosen respondents.

Attribute	Range	Actual number included within the sample of 33 respondents
Gender[a]	Male	16
	Female	16
	Other/Prefer not to say	1
Age	Less than 25	0 (Note: No respondents were <25)
	25–34	5
	35–44	7
	45–54	13
	55 or older	8
Institution	20 options	26 from IoTs
		6 from universities
Academic qualifications	Higher Certificate (Level 6)	Higher Certificate (Level 6)—1
	Ord Degree (Level 7)	Ord Degree (Level 7)—1
	Bachelors (Hons) (Level 8)	Bachelors (Hons) (Level 8)—15
	Master's Degree (Level 9)	Master's Degree (Level 9)—20
	Postgraduate Certificate (Level 9)	Postgraduate Certificate (Level 9)—4
	Postgraduate Diploma (Level 9)	Postgraduate Diploma (Level 9)—6
	PhD (Level 10)	PhD (Level 10)—12
	EdD (Level 10)	EdD (Level 10)—0

TABLE A4 (Continued)

Attribute	Range	Actual number included within the sample of 33 respondents
Discipline of academic qualifications	Engineering Only	15
	Engineering and Education	6
	Other	12—Ranges from Sociology to Architecture to MA in Teaching Maths
Professional qualifications	CEng Engineers Ireland	10
	CEng of other institutions	9
	No professional qualifications	14
Length of time working in academia	<5 years	8
	5–10 years	4
	11–20 years	8
	>20 years	13
Your main role	Mainly Lecturing	29
	Mainly Research	4
	Admin/Management	0 (focus is on teaching, so not as important)
Teaching load	<5 h	0 (very few respondents in the survey)
	5–10 h	8
	10–15 h	5
	15+ h	23
Involved in EI accreditation?	Yes	24
	No	8
Industry experience	Did not work in industry	7
	0–5 years industry experience	5
	6–10 years industry experience	6
	10–20 years industry experience	7
	>20 years industry experience	2
	Still working in the industry	6
Industry role	Little or no management	4
	Project Management	17
	People Management	14
	Senior Management	6
ATI responses	Exceed threshold in Information Transmission/Teacher-focused (ITTF) Scale	2 ITTF
	Exceed Threshold in Conceptual Change/ Student-Focused (CCSF) scale	9 CCSF
Most important skills	Choose outliers in skills list	11 outliers in skills list
Provocative statements	Choose outliers in statements list	15 outliers in provocative statements list

[a]Self-reported options for gender provided on the survey included male, female, or other/prefer not to say. However, it is noted that it would be more appropriate to have provided terms such as man, woman, or other/prefer not to say for this question in line with good practice and the principles of bias-free language.

TABLE A5 Key demographics for interviewees.

	P1 Female[a]	P2 and P3 Industry experience	P4 Work with graduates	P5 Outlier ATI results	P6/P7 PhD no PhD	P8/P9 Educational qualifications	P10/P11 Academic experience	P12 Lecturing P13 Research	P14 Chartered member IEI	P16/P17 EI accreditation	P18 Outlier in provocative statement	P19 Outlier in skills ranking	Total tags
Dermot		>20 years	Yes		No	No		Lecturing	Yes	Yes	Outlier	Outlier	9
Hannah	Yes	None		ITTF	No	Yes		Lecturing	No	Yes		Outlier	9
Nathan		>20 years	Yes	CCSF	PhD	No		Lecturing	No	No	Outlier		9
Muireann	Yes		Yes		No	Yes	<5 years	Lecturing	Yes	Yes	Outlier		9
Nichola	Yes			ITTF&CCSF	No	No	<5 years	Lecturing	No		Outlier	Outlier	9
Kathleen	Yes		Yes		No	Yes	>21 years	Lecturing	Yes	Yes			8
Sean			Yes		PhD	No	<5 years	Lecturing	No	Yes		Outlier	8
Charlie			Yes	CCSF	No	No	>21 years	Lecturing	No	Yes			8
Sebastian		>20 years	Yes		PhD	No	<5 years	Research	Yes	Yes			8
Josephine	Yes		Yes		No	No		Lecturing	No	Yes	Outlier		8
Greg		None			PhD	No		Research	No	Yes	Outlier	Outlier	8
William					PhD	No	>21 years	Research	Yes	Yes	Outlier	Outlier	8
Rosaleen	Yes	None			No	Yes	>21 years	Lecturing	No	Yes			8
Christina	Yes		Yes		PhD	No		Lecturing	Yes	Yes	Outlier		8
Imelda	Yes		Yes		No	No	<5 years	Lecturing	No	No			8
Joe		None			No	No	>21 years	Lecturing	No	Yes	Outlier		8
Monica	Yes		Yes		PhD	No	<5 years	Lecturing	Yes	No			8
Mike		None			PhHD	Yes		Lecturing	No	No			6
Adrian			Information not available for Adrian as they were one of the pilot interviews that were included and they did not complete the survey										

[a]Self-reported options for gender provided on the survey included male, female, or other/prefer not to say. However, it is noted that it would be more appropriate to have provided terms such as man, woman, or other/prefer not to say for this question in line with good practice and the principles of bias-free language.

APPENDIX B

TEMPLATE USED FOR INTERVIEWS

A template (Table B1) was used to help direct the format of the interviews in this study.

TABLE B1 Introductory text and outline of interview questions.

BEFORE WE START:

Any questions on the information sheet, consent form, ability to withdraw from the study, and so on? On that basis, if you could review and sign the consent form for me, please ...

START RECORDING

First, thank you for your time and agreeing to participate in this interview; it is very much appreciated.

The first thing I would like to cover is the information sheet and consent form. I would just like to confirm whether we have discussed the consent form and that you have agreed to be interviewed in line with all of the details supplied on the form.

AWAIT ANSWER

So, let us get started.

I'm undertaking a research study and, as part of that, my data collection involves interviews with academics teaching engineering programs in Ireland.

You have kindly agreed to participate.

The interview will take around 45 min to 1 h, and I will cover four main areas:

- Academic, Industry, and Teaching experience
- Teaching approaches
- Program design
- Thoughts on a couple of other topics if that's okay?

Topic	Key questions	Follow-up questions		
Introduction and settling down	The first thing I wanted to ask about is your industry and academic experience.	"You've recently moved to XXX after some years in the industry. How have you found the move?" "You've been in XXX for X number of years, have you experienced many changes over that time?"		
Now, we'll move on to your teaching approaches				
Teaching approach	Can you list the main modules you teach?	What is your favorite module and why?	Describe a typical session in that module. Why do you put them in groups?	How did you design that module?
Assessment	Describe how the module is assessed.	What are the students examined on?	How did you design the exam?	How do you assess?
Other teaching approaches	Do you do anything differently in any other modules?			Why is it different there?
Let us move on a little more				
Conceptions of professional skills	There's a lot of literature out there now about the skills that engineers need for the workplace, sometimes called "professional skills"	What has influenced your view on that?		
	Can you say what the term "professional skills" means to you?	Why do you say that?		
	Can you complete the sentence—"professional skills are the skills that ..."			

(Continues)

TABLE B1 (Continued)

Topic	Key questions	Follow-up questions	
- Where do you think engineers develop those skills?	Referring to *the program* you mentioned, where within that program are those skills taught?	*Do not know*	Have you been involved in an Engineers Ireland accreditation, was it mentioned there?
		Not taught anywhere	Why do you think that is so?
		Certain modules (not mine)	Which modules?
			How effective do you think those modules are?
		Some of my modules	Describe a typical session in that module.
		Not enough modules	What makes you say that?
Drivers	Can you give me an example of any *drivers* that are initiating this push toward professional skills in engineering programs?		
Experience in Teaching	Have you any experience teaching students professional skills?	Have there been any program committee discussions about where they are developed?	
		In your experience, have you influenced this?	
	How important do you think it is that engineering students develop those skills?	Can you think of any *barriers* that exist that might influence how you can better develop skills within students?	
Program design	Is there anything you would change about the program as a whole?	Is there anything you would change about assessment in the program?	
Background in Academia, mainly, research	Have you any examples of where you have used them in your career?	How, why?	
	Where did you learn your professional skills?		