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Theodora Mavridou
University of Portsmouth, UK

Nikolaos Nanos
University of Portsmouth, UK

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Theodora Mavridou, Nikolaos Nanos

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Abstract

Current trends in engineering have been recording major changes in the mode of operation that require close alignment with academia to ensure the suitability and successful outcome of graduate student employment. In an everchanging environment traditional “hard” aspects of engineering knowledge are essential but do not, by themselves, ensure a graduate candidate’s suitability for a particular post. Increasingly, the industry is observing a “divergence” between academic teaching and industrial practice in terms of the necessary “soft” engineering skills. Results: This project identified the differences between the student and industry professional expectation of those elements of engineering practice that transcend the “hard” elements of the engineering curriculum by focusing on the opinion and desirability of a series of skills such as: Project Planning; Business Planning; Competitor Analysis; Market Analysis; Finance; Health and Safety; Stakeholder Analysis; Strategy; Innovation in Enterprise; Leadership; Risk Management and Ethics. To that effect a set questionnaire ranking those skills in terms of importance and difficulty has been disseminated to student and industry professionals along with two open ended questions that asked participants to identify graduate engineers’ needs and curriculum enhancements. Conclusions: This paper identified and quantified the difference of opinion between students and industry professionals and illustrated the differences in what each perceive as important and difficult leading to a better understanding of the changes in terms of curriculum delivery and expectation management to avoid integration issues of graduate engineers in the industry.

Introduction

Powerful forces, including demographics, globalization, and rapidly evolving technologies are driving profound changes in the role of engineering in society. The changing technological needs of a globalized economy dramatically differ the current nature of engineering practice, demanding far broader skills than simply the mastery of scientific and technological disciplines.

In this framework, the importance of solid engineering understanding is not, any more, by itself the sole desirable hallmark of a successful engineering graduate. The nonlinear nature of the flow of knowledge between fundamental research and engineering application, along with the highly interdisciplinary nature of new technologies demand new paradigms in engineering understanding and application. It is therefore important for all aspiring engineering candidates to not only graduate with the necessary tools of knowledge and research ability but also deeply root in them the desire and mechanisms of perpetual professional development.

One of the biggest challenges of the educational sector, has always been to teach and learn the integration of knowledge, practical skills, and ethical judgement in a setting often removed from actual practice. As the main purpose of Engineering is about solving problems, those cannot easily be taught without the associated constraints on the solution, both on the work activities themselves (i.e. time and cost implications) as well as the nature of the solution provided (i.e. normative aspects).

It is therefore, unsurprising that the field of Engineering Practice teaching currently stands in prominence as it is being recognized as a need not only by practicing authorities (i.e., Professional Institutions and Accrediting Bodies) and the market (i.e., Employers and Clients) but also by educational establishments (i.e., Universities). The fact that Engineering practice is nowadays treated as an important element of the formal Engineering curriculum makes its delivery and content an important aspect of the work and academic training for aspiring engineers. As such, its delivery must be appropriately codified and executed in a way that satisfies those requirements and holds academic and professional scrutiny.

Literature Review

As shown in recent years through the annual Skills and Demand in Industry survey from the Institution of Engineering and Technology there is a discreet discrepancy between industry demands and graduate abilities (Blackmore et al., 2015).

This becomes increasingly the case in terms of engineering practice skills where globalization and the increasing mobility of engineering makes those elements important as graduates are expected to fill different roles in a diverse workspace (Patil, 2005). In that environment engineers do not only require high technical competence or design and manufacturing knowledge but they are also required to have a business organizational understanding and the capability to innovate and create within the constraints and boundaries of the portfolio assigned to them (Mounir 2022; Sheppard et al. 2006). It is therefore important to continuously revise engineering practice and education to constantly be in tune with the changes and demands of the industry and society May and Strong (2006).

It is therefore important to identify from the early stages that professional education, ideally, must reflect practice if it intends to prepare for successful future practitioners. As society deals with political, social, economic, and technological changes; professional practice and professional education often are redefined and reformed to suit societal needs. Engineering is no exception and for the last two centuries, engineering as a practice has affected and has been affected by trends in politics, society, economics, and technology with the successful engineer always being influenced by the past, shaping the present, and affecting the future.

The transformation of demands from an engineering graduate to engineering being perceived, as Koen (2003) describes, “use of heuristics to cause the best change in a poorly understood situation within available resources” necessitating the strengthening of engineering practice skills to ensure success. In the absence of a clear consensus, in terms of which "soft" engineering practice elements are the most important ones (Allen and Van der Velden, 2012; Pereira et al., 2019) the educators should focus on the range of requirements as those are provided from the industry.

Jeffrey et al. (2011) in his work investigating why industry says that engineering graduates have poor communication skills recommends two things in the engineering departments. The first is there is a need for a clear definition of what communication skills the students should learn and the second is to clearly define how we strategically will teach those skills. Those two elements spoke about the linkage between the goals of teaching communication and the goals of teaching engineering. A key part of this process is to ensure that students have a clear idea of the industrial expectations as well as be aware of the challenges and it is in this context that the importance of studying Engineering Practice as part of the Engineering curriculum is becoming clear. With the successful engineer being aware of the context of the problem under investigation as a parameter along its technical hurdle. This requires engineers to work with clients, users, communities and other stakeholders to establish a clear understanding of needs, constraints and potential impacts of any proposed solutions. Understanding the needs and requirements of users, communities, society and the environment, is as important to ethical engineering as meeting the needs of clients or employers.

Gast et al. (2017) stipulation that most professional development activities focus on individual elements, such as mentoring or the use of portfolios illustrates the growing need for students to access such resources if they are to become successful in their careers. Prior work from a number of authors such as Meirink et al. (2010) and Vescio et al. (2008) have demonstrated the positive effects of students participating in a team based professional development intervention. The creation of pseudo professional environments can be a successful method for the development of the professionalism of engineering students. (Berjano et al. 2013). The game-based learning practice can act effectively for teaching engineering students to actively participate and engage with the activity. Following the rules of the games, confront the different barriers and styles of the existing communication and competencies students will gain awareness and experience in a team communication and collaboration with different people. (Cruz et al. 2022)

Dirk Pons (2016) identified through his literature study that the important engineering management skills are those of adaptable problem solving; creativity (ChiKuang, Jiang, and KuangYi et al. 2005); critical thinking (Furterer et al. 2006); and decision-making skills (Furterer et al. 2006). Furthermore, the concepts of systems thinking approaches (Waks and Frank 2000); integrative skills (Marin Garcia and Lloret 2011); a wide perspective of engineering (Waks and Frank 2000); and a multidisciplinary approach (Chan et al. 2002; King 1988; Palmer 2003) have been explored along with engineering economics (Merino 2000); project management (Furterer et al. 2006; Waks and Frank 2000);.quality (Waks and Frank 2000); marketing (Rammant 1988);.teamwork (Furterer et al. 2006); leadership (Furterer et al. 2006; Martin et al. 2005); . Ethical and social responsibility (Zandvoort 2008); Communication (Farr and Bowman 1999; Lappalainen 2009; Meyers et al. 1993; Ravesteijn et al. 2006; Sun et al. 1999).

Barradell et al (2018) recognizes that the curriculum design is an area that not many were discussing about as much other areas in the university life, moreover lastly it is tended for a change. (e.g. Barnett & Coate, 2005; Blackmore & Kandiko, 2012; Fraser & Bosanquet, 2006; Nordquist & Laing, 2014; Parker, 2003). While Beagon, U. (2018) in a study for the importance of the professional skills identified that gender appears to have a big influence and more specifically the importance can differ if the skills are technical over not technical skills.

It is therefore important to identify from the early stages that professional education, ideally, must reflect practice if it intends to prepare for successful future practitioners. As society deals with political, social, economic, and technological changes; professional practice and professional education often are redefined and reformed to suit societal needs. Engineering is no exception and for the last two centuries, engineering as a practice has affected and has been affected by trends in politics, society, economics, and technology with the successful engineer always being influenced by the past, shaping the present, and affecting the future.

One of the biggest challenges, of course, has always been to teach and learn the integration of knowledge, practical skills, and ethical judgement in a setting often removed from actual practice. Engineering work is about solving problems. Because there are constraints on the solution, both on the work activities themselves (e.g., amount of time, money), and on the solution (e.g., cost, weight) engineering work is constraint-based problem solving.

With the majority of "Engineering creativity" emerging within the constraints of physical laws, commercial considerations, the needs of the client or employer, society, the law and ethics, those constraints provide boundaries within which to explore problems and propose engineering solutions.

A great example of the multifaceted nature of engineering and the need for practitioners to be exposed to those "nuanced" ideas as part of their curriculum is the all-important element of ethical considerations that constantly gains traction and prominence as an engineering driver. There are many examples of how ethical considerations can and do shape engineering in the modern world where outcomes are not always measured by their technical completeness and prowess. In that effect, ethical considerations in relation to safety and the environment can provide opportunities and inspiration for engineers to devise innovative solutions, directing their creativity to improve the performance of engineering technologies and systems. Additionally, ethical concerns about climate change drive engineers to devise creative solutions to the problem of providing reliable, cheap renewable energy. While, ethical concerns about global poverty led engineers to work with local communities to develop new technologies for water supply and sanitation in the developing world and acts as a constraint to bad practice and an inspiration to innovation and creativity.

Method

The study employs both qualitative and quantitative research methodologies. With questionnaires disseminated at both students as well as industry professionals the work aims at highlighting the differences in approach of elements of engineering practice and their relative importance. Using the literature review mentioned earlier a set of questions has been conducted where both students and engineers participated. All subjects have been asked to reply using the same questionnaire and short question format.

This methodology has been selected to involve both industry leaders as well as educational participants revolving around the three research questions that guide this qualitative study as follows:

- Which are the most important topics that should be introduced to an Engineering Practice module?
- Which is the difficulty of understanding these topics and the difficulty of implementation in the industry
- Which skills a graduate should have from the employability perspective.

To answer these questions, Level 4 students of Engineering Practice (M30039) were asked to participate and answer a set of questions while people from industry with positions in Project Management and Principal Engineer have also been asked to provide their opinions. Data collected from the interviews were then related to categories previously defined from the literature review.

The study initially identified a key research question, derived from the study brief which was formulated into: “Which are the current skills that a graduate engineer needs in the industry?”

- This led to a further four subsidiary research questions:
- How Important you find those different topics in an engineering practice?
- How Difficult you find those different topics to implement in an engineering practice?
- What does industry need from Higher Education engineering graduates?
- What more/else could be done to better enable universities working together with industry to meet these needs in the future?

The first two of these questions were addressed primarily through existing literature (i.e. the EE21C report), but also all relevant and recent UK and international publications.

Results

The results obtained provide an insight into the inherent differences in the understanding of the importance and difficulty of implementation from the two different parties. Those results do indeed show a diversion between what Students believe is of importance to the industry and what the industry expects. To identify those trends a quick test would be to gauge the average importance bestowed in each element from the respective groups as shown ranked in respect to perceived industry importance in Table 1.

Table 1. Importance of Engineering "Soft Skills" Importance (05 max)

Student		**Industry**	
Project Planning	4.0	Ethics	4.3
Business Planning	3.9	Health and Safety	4.3
Competitor Analysis	3.9	Leadership	3.8
Market Analysis	3.8	Business Planning	3.7
Finance	3.8	Market Analysis	3.5
Health and Safety	3.6	Project Planning	3.5
Stakeholder Analysis	3.6	Strategy	3.5
Strategy	3.5	Finance	3.5
Innovation in Enterprise	3.4	Risk Management	3.3
Leadership	3.4	Competitor Analysis	3.2
Risk Management	3.2	Stakeholder Analysis	3.0
Ethics	3.1	Innovation in Enterprise	2.8

Immediately, the difference of opinion between the student body and industry professionals becomes apparent with elements such as Ethics, H&S and Leadership diverging quite significantly between the two groups.

As the perceived importance of those elements cannot fully describe the interconnection between those elements the perceived difficulty of implementation has also been queried to both groups. This was done to allow for better understanding the dynamics between the student body and the industrial expectations. Table 2 provides the average perceived differences between the two groups

Table 2. Difficulty of Engineering "Soft Skills" Difficulty (05 max)

Student		**Industry**	
Market Analysis	4.0	Ethics	3.3
Business Planning	3.8	Strategy	3.3
Strategy	3.8	Leadership	3.3
Leadership	3.8	Project Planning	3.2
Finance	3.8	Risk Management	2.8
Stakeholder Analysis	3.6	Finance	2.8
Competitor Analysis	3.5	Market Analysis	2.7
Innovation in Enterprise	3.4	Health and Safety	2.5
Project Planning	3.2	Business Planning	2.5
Ethics	3.1	Competitor Analysis	2.5
Health and Safety	2.9	Stakeholder Analysis	2.5
Risk Management	2.9	Innovation in Enterprise	2.5

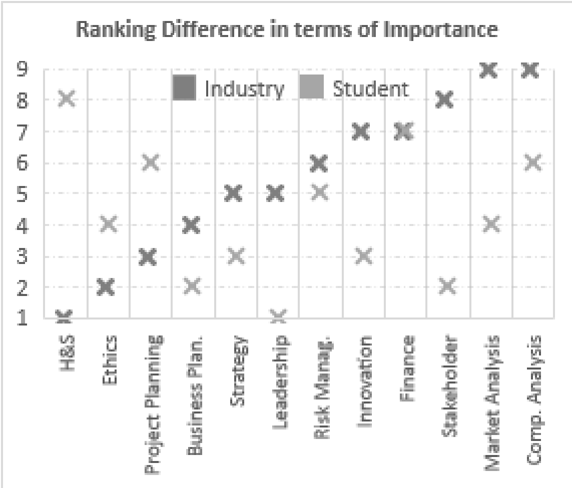
Here, once more one can observe the divergence between the perceived difficulty of implementing elements of Ethics, Risk Management and Project Planning. To help with this distinction Table 3 provides the ranked list from both student and industrial bodies in terms of importance and difficulty of implementation. The ranking uses the industry's results as the "golden standard" on which the student results are gauged upon.

Table 3. Engineering "Soft Skills" Ranking Difference between Industry and Students

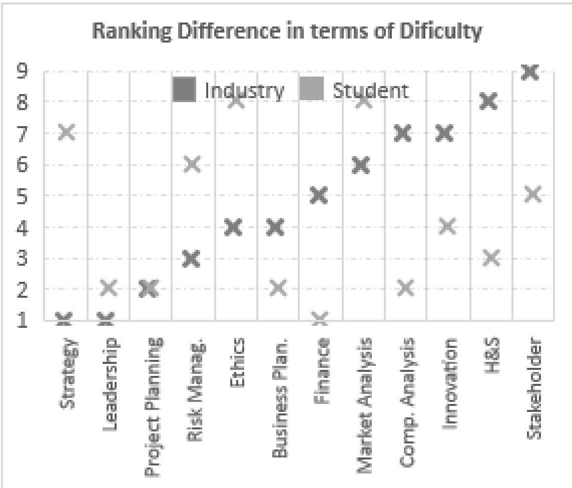
Engineering Skill Importance (Ranking)			**Engineering Skill Difficulty (Ranking)**		
	Industry	**Student**		**Industry**	**Student**
Health and Safety	1	8	Strategy	1	7
Ethics	2	4	Leadership	1	2
Project Planning	3	6	Project Planning	2	2
Business Planning	4	2	Risk Management	3	6
Strategy	5	3	Ethics	4	8
Leadership	5	1	Business Planning	4	2
Risk Management	6	5	Finance	5	1
Innovation in Enterprise	7	3	Market Analysis	6	8
Finance	7	7	Competitor Analysis	7	2
Stakeholder Analysis	8	2	Innovation in Enterprise	7	4
Market Analysis	9	4	Health and Safety	8	3
Competitor Analysis	9	6	Stakeholder Analysis	9	5

A this point it is good to identify an interesting point that presents itself in terms of perceived difficulty where the industrial respondents identified Ethics, Strategy and Leadership as the most "difficult" elements banding together H&S, Business Planning, Competitor and Stakeholder Analysis along with the Innovation in Engineering as the least "difficult" to find/implement. Upon further discussions it became apparent that those elements are not the ones that engineers from the industry find themselves in a hurry to task young engineers with. With that in mind

Table 3 clearly identifies said disparity with Figures 1a and b further illustrating those points exhibiting quite vivid differences in opinion of important elements of Engineering Practice.



(a)



(b)

Figure 1. a) and (b). Ranking Difference of Opinions between Student and Industry bodies

In terms of open-ended questions several important points have been highlighted from the industrial respondents in terms of "What does industry need from Higher Education engineering graduates?". In that regard the following items have been

Table 4. Industry Responses Regarding Graduate Engineers' Needs

Understanding problems, analyzing them and providing solutions in a protective manner.
● Humbleness, Multicultural philosophy, Vision, Resilience ● It needs graduates who will be specialized to a specific sector but also be ready to adjust to a continuously changing working environment.

Understanding problems, analyzing them and providing solutions in a protective manner.
● It depends on the engineering field and specialization. But I'd say collaboration and inclusivity are amongst the top ones, being able to take initiative and learn from mistakes, courage to take responsibility and a visionary, yet humble, mindset.
● Work ethics, good attitude, willingness to learn, collegiality
● Good understanding of engineering, MS office skills, some software skills, organization skills, communication skills. They will need to be able not only to do the work (for which training will be provided) but also to record it and issue it in a clear and structured report.
● Better understanding of supply chains. The soft skills of critically assessing the progress and status of a project, also ability to work with stakeholders, negotiating and challenging when necessary
● Technical brilliance. Great scale of knowledge. Skills on real life engineering aspects rather than theory itself. Managerial skills. Computer excellence. A deep comprehension of Value, Cost of Quality and Cost-efficiency issues.
● Flexibility, innovation, critical thinking, team work
● Bridge the gap between academic training and practice. Lifelong learning, adaptability

On the other hand, some key answers to the question: "What more/else could be done to better enable universities working together with industry to meet these needs in the future?" provide some further insight to the needs of the industry and can help with the better alignment of the academic provisions between university and labour market, pointing out this articulation as a need to overcome the lack of perceived practical competencies and improve on the transferable skills that most.

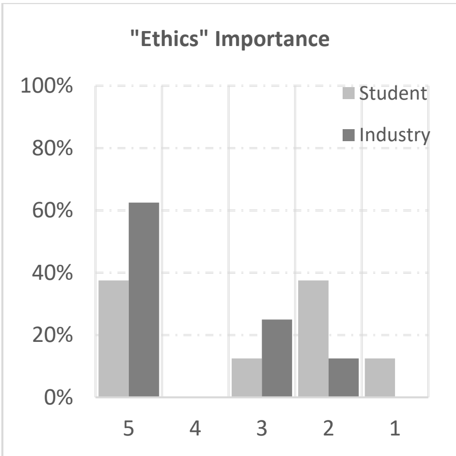
Table 5. Industry Responses on Potential Curriculum Improvements

Provide training programs with an on-the-job approach
• Leadership program, public speaking to increase integration with corporation
• Close cooperation of universities with the industry. Accept more graduates as interns and motivate them appropriately to perform while doing their internship.
• provide students with opportunities for internships, field trips to companies and involve them with on-the-job training (e.g. summer projects).
• Improve communication and collaboration, enable academics to spend time in industry, make collaborative projects easier to be accessed
• The students to be given the opportunity to visit different type of practices of their field to understand what they do exactly, how they operate and what does it to take to succeed in
• Big employers have the resources and training capacity but smaller employers give you the benefit of being exposed to most parts of the project so recruitment shouldn't just focus on the big engineering firms but on smaller practices too.

Provide training programs with an on-the-job approach
• Internships on a regular basis. Dissertations on real data case studies
• establish communication channels between universities and corporate management so the market needs to be streamlined in real time. -establish a mixed steering committee to identify gaps and opportunities. -stronger and meaningful apprentice programs.
• More collaboration e.g. visiting lecturers from the industry, involvement with the industry

Discussion

With the above in mind a few select elements, presenting rather interesting case studies for elaborating on such a disparity have been selected. The merit of such a selection is based on the differences between the student and industry replies. Figures 2, 3 and 4 (a) and (b) identify such points for the elements of Ethics and H&S as being ranked as very important by the industry but not so by the student body.

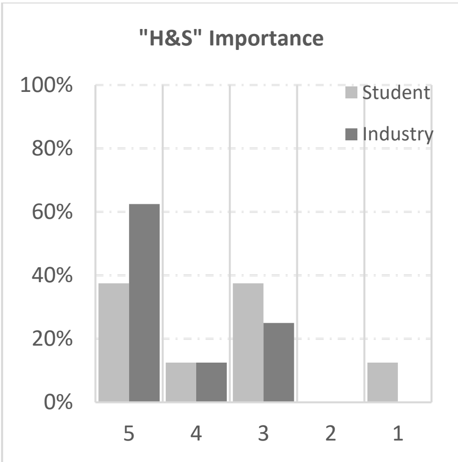


(a)

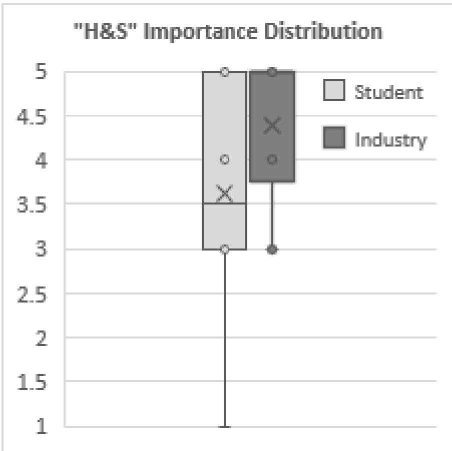
(b)

Figure 2. a) and (b). Difference of Opinion in the Importance of "Ethics"

Figures 2 (a) and (b) show one of the most interesting results that should, if nothing else, bring forward a more robust dialogue regarding the perceived importance of Ethics in the engineering practice. One can see the difference between the industry professionals and students with the first ranking it towards the top of importance while the later being quite ambivalent in terms of importance. Results such as those should be used to “kick start” the discussion around the importance that industry bestows on such a key element of engineering practice.



(a)

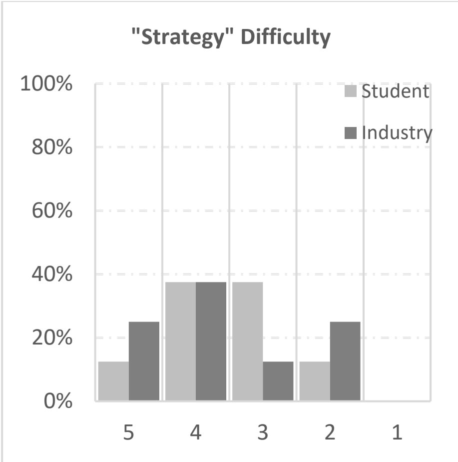


(b)

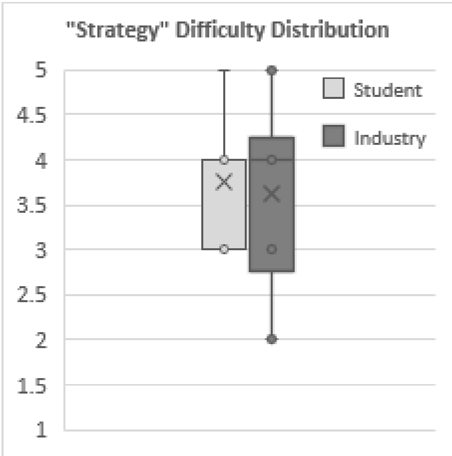
Figure 3. a) and (b). Difference of Opinion in the Importance of "H&S"

Figures 3 (a) and (b) further demonstrate the aforementioned “divide” between industry and student expectations regarding the importance of different elements. Once more, one must consider said results while keeping the absolute ranking as shown in Tables 1 and 2 as well as Figures 1 (a) and (b) that clearly illustrate such an event that highlights the need of academics to start from an early point the students’ initiation to those elements.

To further those points in terms of perceived difficulty in finding and implementing said elements of engineering practice a few more interesting examples stem from the results in terms of disparity between student and industry expectations of difficulty. In that respect Figures 4 (a) and (b) identify the way students and industry replied in terms of distribution which, in isolation, would incline researchers into showing some congruence.



(a)



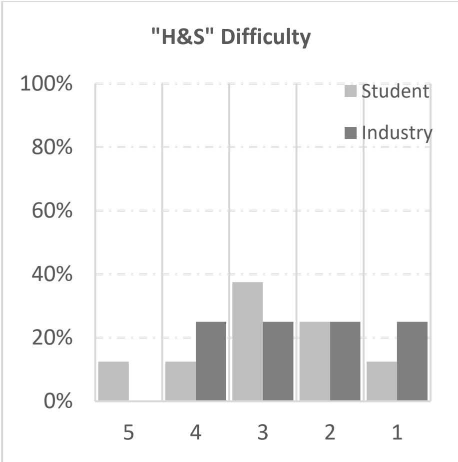
(b)

Figure 4. a) and (b). Difference of Opinion in the Difficulty of "Strategy"

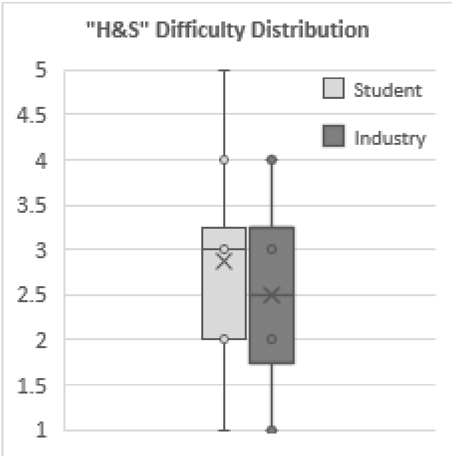
Those results should, though, be reviewed along with the absolute rankings of Table 3 and Figures 1(b) where it becomes clear that despite the apparent similarities presented in the voting distribution the disparity in perceived difficulty remains high with a large disparity between the ranking between the industry (Ranked 1st) and student body (Ranked 7th). It therefore becomes a clear point in need of disambiguation with students.

In addition to the above, the Health and Safety aspects of engineering practice seem to also suffer from disparity in regards to the difficulty in implementation with the industry ranking it almost last (Ranked 8th) in contrast to the student body (Ranked 3rd).

Such a difference can be attributed to the conceptual difficulties of what Health and safety in engineering practice entails. In that respect industry professionals have worked with the relevant protocols and therefore feel more at ease with the concepts and implementations while the student body feels that this is a convoluted subject and ascribe to it a high difficulty ranking.



(a)



(b)

Figure 5. a) and (b). Difference of Opinion in the Difficulty of " Health and Safety"

Conclusion

It is in this context that the importance of studying Engineering Practice as part of the Engineering curriculum is becoming clear. With the successful engineer being aware of the context of the problem under investigation as a parameter along its technical hurdle. This requires engineers to work with clients, users, communities and other stakeholders to establish a clear understanding of needs, constraints and potential impacts of any proposed solutions. Understanding the needs and requirements of users, communities, society and the environment, is as important to ethical engineering as meeting the needs of clients or employers.

Working with a range of stakeholders can provide additional constraints and inspiration for creative design, leading to solutions that are more likely to have positive outcomes. When the needs of the wider community and environment are in conflict with the requirements of employers or clients, engineers are faced with creative and ethical dilemmas. In some circumstances it may be possible to devise creative solutions that address seemingly conflicting requirements.

For this to be a successful endeavor the importance of a solid understanding of the Engineering in Practice becomes apparent and can act as a guide to young practitioners at their first steps and for the rest of their professional careers as it prepares them for the ever changing nature of engineering practice.

Such empirical work can form the basis of academic reform of curriculum that will better align with industrial requirements without overcompensating with removing important elements that could be missed from the industry. In that sense one must be aware that the elements highlighted as the ones that are highly valued by the industry are there exactly because the other elements have been delivered in the first place. Under that light it is important to make sure that any recommendations for future action are additional to the currently taught curriculum rather than take the place of other elements of engineering practice teaching.

It therefore becomes clear that boosting employability and job retention could be achieved and the students compete successfully in this dynamic global context, effective communication and interpersonal skills are essential and the curriculum should promote environmental, economic global awareness, problem solving ability, engagement with information technology, self-directed learning and lifelong learning communication, management and teamwork skills.

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Author Information

Theodora Mavridou
https://orcid.org/0009-0002-0080-1492
School of Mechanical and Design Engineering
University of Portsmouth
UK
Contact email: *dora.mavridou@port.ac.uk*

Nikolaos Nanos
https://orcid.org/0000-0002-6014-2874
School of Civil Engineering and Surveying
University of Portsmouth
UK