Mindful engineers in a sustainable engineering

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According to the *Encyclopædia Britannica*, the «oldest national scientific society in the world», the Royal Society of London for Improving Natural Knowledge (known as Royal Society), was established on November 28, 1660. In 1818, the Institution of Civil Engineers (ICE), the first professional engineering body, was also set up in London. Ten years later ICE got its Royal Charter granted by King Georges IV. Throughout these last two hundred years, the world, and West societies in particular, have experienced deep social changes. The engineering profession has not been an exception, and today its ethos is much broader and complex than the roots and conditions we can find at its origins. What elements are required in the professional self-awareness of twenty-one century engineers? In what follows, our goal is to outline what these characteristics of contemporary engineering could be.

Professional self-awareness

As a starting point it is perhaps opportune to remember that acting as a responsible professional includes keeping always in mind that oneself is at any time personally involved. In other words, being a responsible professional implies having a role in how the practice of the profession contributes to society, as well as considering the effects that their own attitudes and actions have on the profession. Certainly, these features, far from being a distinctive characteristic of engineering, are common to all professional activities. Given this assumption, professional self-awareness can be understood as "[…] a method of practical reflection mediating between the professional's reasoned assessment of the ends toward which the profession ideally aims and the specific situations and intentional dispositions that motivate the professional's behavior within the profession." [1, p. 125].

Thus defined, engineer professional self-awareness incorporates two dimensions. First, a *technical* dimension, which includes, among others, scientific knowledge, techniques, and abilities required to be a competent professional. Second, a *social* dimension, which includes elements such as values, ends and principles required to be a committed professional. These dimensions are quite different, but both have to be taken into account because they complement each other throughout the professional activity. Separately, neither good intentions nor good know-how guarantees by themselves a good result.

It is not surprising that the technical dimension of self-awareness is easily and widely recognized and accepted by engineers. Most of their education as engineering students is focused on these aspects (mathematics, physics, chemistry, technologies, etc.) and they are willing to learn whatever knowledge is required after acceding to the profession. However, the social dimension easily sows more dissensions when it appears on the stage. From the academic point of view, this aspect is often included in the wide field of engineering ethics, and it is tackled in the classroom through the presentation of professional codes or the study of cases, among other resources. That said, the teaching of engineering ethics is not our subject here. For our purposes, at this moment it is enough to point out that the social dimension of professional self-awareness becomes much more apparent whenever the engineer does not confuse the aims of the profession with her personal goals. That is to say, when the profession is considered a form to serve society and the engineer herself someone who contributes to an open-ended social enterprise, instead of a means to earn money or to succeed.

Evolution of professional engineering ethos

The set of elements to be considered in professional self-awareness is dynamic, and over time has gravitated around different values according to the evolution of professional engineering ethos. C. Mitcham [2, pp. 50-55] distinguishes three historical stages. As they are useful to understand our present stage characteristics, precisely the ones we will consider later in more detail, it is convenient to identify briefly the core of these three periods. The first stage begins in the XIXth century with the establishment of institutions specialized in engineering education, which held in common the fact that they were ruled by military administration. Consequently, the main values assimilated by those engineers were closely related to loyalty, discipline, and obedience to the authority. The second stage begins with the XXth century and reflects the growing reputation engineers had been acquiring in society. Progress seemed to be in their hands, and it was assimilated to the principles of rationality and efficiency. Politics and economics were also under this technocratic influence. Finally, a third stage emerges at the end of Second World War. The euphoria of the first years of the century is over and new social concerns are at stake, public safety, welfare and social justice among them. Thus, engineering also reflects these changes through the incorporation of natural environment and sustainable development among its new concerns. Lately, citizen participation in engineering decision-making is also progressively being recognized as a desirable democratization.

Global engineering and the UN 2030 Agenda

One of the features that defines the beginning of this century is the growing acceptance that our world is one, diverse but strongly interrelated and interdependent. This is true, not only when considering life and environment, but also when analyzing economy, politics or culture. A phenomenon of interaction often referred to as globalization. Together with this recognition comes the realization that many global issues (food and water, health, climate change, refugees and migration, children and women, to name a few) should be tackled jointly, although the different groups involved shall act according to their capacities and responsibilities.

On September 25, 2015, the General Assembly of the United Nations approved, unanimously by the 193 countries represented there, the resolution A/RES/70/1 *Transforming our world: the 2030 Agenda for Sustainable Development* [3]. This Agenda defines seventeen Sustainable Development Goals (SDG) expanded across a set of 169 specific ends, which seek to stimulate and direct those initiatives and policies that should be carried out in the world throughout the period 2016-2030. The 2017 official report on the results accomplished during 2016 and 2017 is already available [4]. Two characteristics distinguish the Agenda from other previous international initiatives (e. g. the eight international development goals established by the *United Nations Millennium Declaration* [5]). First, the formulation of the three pillars required for a real sustainable development: social, environmental and economic. They are so closely interrelated that they require to be tackled together. Second, the Agenda is relevant to all countries in the world, not only to developing ones, although each national government will set its own national targets in accordance with its specific circumstances.

Many engineering tasks and projects are related to the topics considered by the seventeen SDG. For instance, SDG 6: Ensure access to water and sanitation for all; SDG 7: Ensure access to affordable, reliable, sustainable and modern energy for all; SDG 8: Promote inclusive and sustainable economic growth, employment and decent work for all; SDG 9: Build resilient infrastructure, promote sustainable industrialization and foster innovation; SDG 11: Make cities inclusive, safe, resilient and sustainable; SDG 12: Ensure sustainable consumption and production patterns, and SDG 13: Take urgent action to combat climate change and its impacts. For these reasons, engineers are also called by the Agenda to take part in this endeavor, to assume and use accordingly the power of their influence [6]. The purposes, values, resources, means, processes and final products related to their professional activities always have an influence on some aspects of sustainable development. A timely chance has arisen to make the world a better place, and to enrich engineering practice. This is the new scenario where our main question is

put, namely: What are the features that competent and committed professional engineers should consider to adapt themselves to these global challenges?

Mindful engineer

For the sake of simplicity, we will refer to mindful engineers as those engineers matching the profile of both a competent and a committed professional and who are willing to foster sustainable development in their professional practice. Likewise, we are going to refer to the professional performance of this mindful engineer as mindful engineering. Probably, the new characteristics required by the mindful engineer can be better introduced when they appear as complementary to the set of characteristics we find in the traditional engineer, the professional historically situated in the XXth century. For this reason, we start with a list of ten widely acknowledged characteristics in the profile of traditional engineers [7]-[8]-[9]. These characteristics are obvious and do not require further explanations. Of course, this list is debatable and other sets of characteristics could be presented instead. But our purpose here is not to explore the traditional features of engineering but the new ones, thus we use the list just as a contrast, as an indication of what could be expanded and enriched and how it could be done. Our goal is not, in any sense, to replace these traditional characteristics.

List of traditional characteristics

1. Synthesis ability.

2. Practical creativity.

3. Logical reasoning.

4. STEM education.

5. Problem-solving capacity.

6. Oral and written communication skills.

7. Ability to work in multidisciplinary teams.

8. Willingness to continued learning.

9. Attention to details.

10. Masculinity features.

List of complementary characteristics

Now, we introduce the ten new characteristics associated to a mindful engineer. The function of each one of these characteristics is to expand, or complement, the corresponding characteristic in the previous list. All of them are inspired by the 2030 Agenda, in the sense that they reflect, or are implied in, some of the sustainable development goals described there.

1. Wide comprehension of the context.

In a world with ever growing interrelationships, interdependencies of all kinds cannot be ignored. Science, technology, economy and politics are no independent realms, they have never been, but today this is still more apparent. Engineering activities are not an exception to these global dynamics. Investments in research, the development of new products and systems, the technologies that prevail, the obtaining of raw materials and their trade or the relocation of production are some of the daily factors that have a significant impact on different regions and societies of the planet.

2. Ability to work with diverse and limited resources.

Global engineering should be flexible and adaptable, as it requires the ability to work with different kinds of resources available in each place and situation. Real engineering problems are not always like the standard problems analyzed in a laboratory or a classroom. Even when the most suitable technology is not at the engineer's disposal, when materials and supplies are scarce, or when infrastructures are far from optimal, some solution is expected, and it cannot wait indefinitely for an unlikely betterment of the current shortcomings. Perhaps, this means to awake to what genuine engineering creativity is really about, when uncertainty emerges and the comfort zone is lost.

3. Ability to guide oneself in complex environments.

Complexity may appear suddenly in the form of a diffuse and non-controllable difficulty, when either not all the significant information is available, or because it incorporates heterogeneous demands that are not straightforward to integrate in a spreadsheet. Also, unexpected problems may occur when a technological product or system is transferred to a setting where it was not designed for. For instance, this has happened in Third World countries when aid programs have routinely transplanted technological products from First World countries [10]. In such cases, logical thinking might be not enough because formal logic cannot easily manage exceptions or ambiguous premises. Hence, the engineer must be ready to guide herself across a situation that requires going beyond technical routine and standard procedures.

4. Consciousness of social responsibility.

This aspect synthesizes many of the needs that arise in global engineering that do not depend on science, mathematics or technology. It urges to making some values come true. Particularly, those values that the professional codes already collect as fundamental when conducting the profession, that is, to service the social progress and welfare of people. Unfortunately, professional codes quite often point to the minimum considered necessary, and they cannot provide particular instructions. Therefore, this consciousness defense of the common good must be already present in the engineer, otherwise it will not appear, out of the blue, when the context becomes challenging.

5. Consciousness of environmental issues.

There is accumulated evidence that the environmental impact produced by the way of life and industrial production that prevail worldwide have reached a critical point, which poses a serious risk to the continuity of both human and non-human live [11]. Concepts like prosperity, progress, growth, earth resources, and human well-being should be critically revised in this new global context. Therefore, engineering should always be acting accordingly, that is, diminishing the waste of energy and the devastation of the environment that are imposed by our economic system. Certainly, engineering can contribute to move on in this direction by offering new feasible and sustainable alternatives.

6. Ability to listen, observe and question.

It is essential to leave aside the old idea that, as a qualified professional, one always knows, by default, what is best in each case. This deaf and blind attitude may bring about decisions that diverge greatly from what people really need. Instead, an attitude more open to listen, observe and question, may become significantly beneficial for both sides. This is just another way of recalling that professionals should be open and willing to reconsider their ideas about how things should be, especially when sensible petitions do not come from colleagues. Engineering education plays a central role here. Global engineering requires a new education oriented to engaging students by stimulating new ways of learning, different from the old teacher-student pattern based on authority, repetition and dull acquisition of some packed knowledge [12]-[13].

7. Ability to integrate in interdisciplinary teams.

The multidisciplinary collaboration can be distinguished from the interdisciplinary one in the sense that the former is about being able to cooperate in teams made up of specialists from different fields, where each one deals, alone, with their specialty. In interdisciplinary collaboration, on the other hand, it is expected that the different specialties, without giving up their ways and goals, try to converge in a constructive way to arrive at, perhaps unexpectedly, richer and more integrated solutions. Sometimes, multidisciplinary collaboration is still perceived as unavoidable, a lesser evil. Instead, interdisciplinary collaboration opens up a creative opportunity that should always be welcome. For instance, it appears at the inner core of sustainability research [14].

8. Sensitivity to social, cultural and natural diversity.

One of the non-quantifiable assets humanity possesses is diversity in the social, cultural and natural fields. Valuing and protecting it benefits our individual and collective health. Engineering can also contribute to its defense through the recognition of the necessities and different ways of living adopted by communities and territories. For engineers, learning can be something more than mastering new sophisticated tools and techniques. It could mean the discovering of how their capacities can be adapted to the specific requirements of particular societies, instead of applying standard patterns, which are generally insensible to circumstances. Moreover, engineers would also have to consider and avoid certain biases in their algorithms and designs, against cultural or social groups.

9. Attention to global changes and innovation.

Changes are no longer surprising news appearing from time to time. Continuous transformations, induced or spontaneous, are the norm every day, everywhere. Independently of the field, being sensitive to these dynamics makes it possible, although not always easier, to take advantage of the circumstances and opportunities that may arise. Engineering innovation is not only limited to improving the design of new tools, machines and techniques to be used in advanced societies. It should be also open to gain a broader scope, to meet in a creative way both old and current necessities from different groups and countries.

10. Femininity features.

Engineering is still a profession dominated by men. According to [14] the 2014 US percentages of women working in engineering compared to men are regularly low. As a sample, these specialties: Civil 16.5%, Aerospace 15,6%, Computer hardware 15,3%,

Chemical 13%, Electric and Electronics 12,3%. Therefore, masculinity features impose themselves over femininity ones, and the result of this bias greatly impoverishes the possibilities of engineering. Moreover, this discriminatory set up often goes unnoticed and, in consequence, remains protected and uncriticized [15]. Some masculinity features we could name at this point are: results-oriented procedures, hierarchical relationships, strength and competition, among many others. The femininity features that could counterbalance them would be process-oriented procedures, interpersonal relationships, support and collaboration [16]-[17]-[18]-[19]. This shift is certainly difficult because it depends on many social factors (gender is a social construction). New integrative visions at all levels of education and determined legal regulations should be part of the required change.

It is worth to remember that engineering usually needs both engineers and organizations. In this sense, sustainable engineering seems to require mindful engineers working in mindful organizations. What the features and the role of mindful organizations are, is the goal of many recent researches [20].

Facing the future now

A scholar interest for the most valued skills and attributes in an engineer profile is nothing new. As a good sample, twenty years ago D.Q. Nguyen [21] studied this subject through a set of surveys distributed to people from three relevant sectors: academics, industry, and students. Her findings were grouped into three categories of qualities: essential, desirable (not essential but recommended), and advantageous (not essential but beneficial). Among the essential qualities acknowledged by the three sectors arouse many of the characteristics of the traditional engineer presented above. However, they also included the ability "[...] to understand the impact of their work on the environment and […] to minimize or prevent damage to the environment" and the need to "[...] have a broad understanding of economic and political structures and the relationships between different countries." [13, p. 73]. These are still current priorities for the engineering profession, even more when the claims of the 2030 Agenda are taken seriously. Therefore, the *ideal* engineer, the one that may not exist but can be used as a guide and horizon in the strive for excellence, can be conceived of as the engineer that is able to integrate the best of the well-known tradition with the demands of our uncertain present. Perhaps, *balance*, in the sense of dynamic harmony, could be a key word to synthesize what kind of mindful engineer for a global sustainable development has been sketched along these lines.

Compared to our predecessors the current potential of technology and engineering is astonishing. Many old dreams are about to come true. But power alone does not

guarantee accomplishing. Much more wisdom should accompany our endeavors. As human beings, we already have the means to succeed, but we keep wandering because we do not share any valuable common goal yet. It seems that amid technical progress something essential has been forgotten. For the next generations, is a sustainable world just an option?

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