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SCIENCE & TECHNOLOGY EDUCATION FOR 21ST CENTURY EUROPE

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IN COLLABORATION WITH TASK FORCE S&T EDCUATION FOR THE 21ST CENTURY

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INTRODUCTION

European societies change due to the impact of new technologies and developments in the economy and in society at large. The digital transformation changes every part of engineering, science and technology in a yet unknown intensive way. Soon everybody will have access to practically infinite data, practically infinite processing power, at practically infinite speeds. Universities play an important role, preparing students for a labour market that is undeniably moving towards the use of emerging technologies. There can be no doubt that these institutions are not keeping up with these rapid technological, societal and economic changes. In the 21st century, 20th century solutions and thinking are not going to get the job done.

To be future-ready and remain relevant in the Volatile, Uncertain, Complex and Ambiguous (VUCA) world, in an ever more competitive global landscape, higher engineering education in Europe needs a dramatic realignment. The knowledge society is in a state of transition to a global learning society. It is no longer the creation and dissemination, but the acquisition, sharing and collaborative collection of knowledge that have become the key factors of success. Learners create their own playlists. Teaching staff have to rethink their role.

There can be no doubt that mastering depth in technical engineering disciplines and logical thought has always been, and will always remain, necessary for successfully analysing problems, designing solutions and advancing knowledge, now and in the future. To prepare students for the knowledge-based economy, engineering education has to focus on the acquisition and development of core knowledge and capabilities in the domain of the engineering sciences: to discover, analyse, conceptualise, design, develop, operate and innovate complex products, systems and processes. These attributes are hard-won and only come with practice and experience.

Educating the next generation of responsible engineers is the biggest impact universities have on society. It's the engineering graduates who make the difference by combining technical expertise with personal and professional attributes for effective leadership. No longer do universities have to prepare their students for success in their first job, but for success in future learning, work and life. The graduates shall not only have learnt to cope with the changing world but being change makers themselves. They shall have learnt the literacies, skillsets and mindsets they need to thrive in the world of Industry 4.0 that will further evolve into a 'Society 5.0', where knowledge will not only be created by humans, but increasingly by algorithms in intelligent machines from an abundance of sensor data. Universities shall continue providing them with access to the learning they need, to face the uncertain challenges to be faced by their generation.

> "Engineering students have to learn that people policies, environmental aspects, politics, economics or cultural values often override disciplinary expertise."

The role of universities in today's VUCA society in Europe are changing rapidly. New actors and new educational approaches are appearing. Universities of Science and Technology (S&T) in Europe have not felt much urgency in the past to make societal contributions. But the universities in our network cannot be complacent and just react. They shall help create this transformation as the architects of the future.

The digital transformation and globalisation will hit the academic organisations, affecting entire study programmes. For instance, data literacy has to become an integral part of each study programme. But more important, the educational changes shall not be limited to the breakthroughs and exponential advancements in technologies. It may be even more important to build educational change upon what technology *cannot* do and is strictly human!

S&T universities have to become much more socially-engaged and culturally open to remain relevant, and take the lead. They shall no longer produce knowledge *for* the world alone, but have to become more active *in* the world. 'Impact-focused education' will therefore become the leading motto.

This discussion paper is an exploration of the trends in engineering sciences and technology, education and society, and an orientation how our association could take the lead in changing higher engineering education in Europe.

CHANGING LANDSCAPE OF S&T IN THE AGE OF ACCELERATION

The world is changing rapidly, is increasingly complex, often chaotic, and fast-flowing. We are on the threshold of the fourth industrial revolution, built on the revolution of globalisation, digitalisation and hyper-connectedness. It will lead to unprecedented paradigm shifts in engineering and technology, economy and business, on societal as well as individual level.

The three converging driving forces behind this transformation are (Kamp, 2016):

1. Globalisation and digitalisation that actually impact any job, any problem, solution or innovation in all disciplines. Data, Algorithms, high-speed Networks, the Cloud, and the Exponential Moore's Law (DANCE) (Friedman, 2016) will revolutionise the ways we think, communicate, design, work, move, play and do business.
2. The horizontalisation of the socio-economic world in which the traditional hierarchies are being replaced. Horizontal communication through interdisciplinary networks and collaborative models remove the disciplinary compartmentalisation in engineering. More power is transferred to consumers and end-users, who demand that "products and services that are marketed on a global scale, feel local, personalised, and one-off".
3. The blending of technical, economic, and societal cultures, which leads to access to easy-to-use software, tools and equipment, along with free, perfect and instant access to an infinite amount of information goods. It revolutionises the way things are designed, manufactured, financed, sold and consumed.

TO CHANGE THE WORLD, ENGINEERS HAVE TO BE TAUGHT DIFFERENTLY

Do today's S&T universities prepare students sufficiently for the hyper-connected world and the enormous impact of the monopoly power (Foer, 2017) Google, Apple, Facebook and Amazon (GAFA) companies have on society, engineering and technology? Do they educate the students to become ´comprehensivists´? Do they know how many specialists with deep knowledge in a narrow specific field are still needed in the 21st century? And have they anticipated to benefit from the students who are much smarter and mature in digitalisation than staff? Do they know how to respond to the trend in the world of work that engineers will be needed with a higher level and broader understanding of multiple fields, as systems become more complex?

In the rapidly changing landscape of engineering and technology, engineers play a crucial role. Increasingly they will compete in a labour market where intelligent machines work alongside engineering professionals of flesh and blood.

S&T universities have to prepare their graduates to cross the border of their specialism and communicate with people who have backgrounds in other technical or non-engineering disciplines and from different cultures. In this world where boundaries are blurring we have to teach our engineering students to respect the ideas and ways of working that are common in other disciplines and to stay open to other culture and work environments. The days of the solo researcher or solo designer have come to an end.

The super smart society, indicated by Japan as Society 5.0, in which the cyber space of data and information has fused with the physical space of the real world, presents opportunities and great challenges. The changing paradigms mean that engineering professionals have to be agile and resilient, and need skills that go beyond the 'traditional' engineering skills, such as holistic thinking, the ability to work in interdisciplinary global teams, and ethical leadership.

Collaboration across locations and disciplines is increasingly at work. Engineers not only collaborate in teams to solve complex problems, but also have to manage people, and increasingly will have to collaborate with robots. Communication and collaboration are widely regarded as key assets for engineers. Digital work makes working relationships more complex.

Although the teams and team members are more connected, the social relationships are more fragmented and impersonal than twenty to thirty years ago.

The 21st century presents huge challenges that have never been seen before with impact for mankind. Climate change, energy transition, over-population and ageing, mega-cities and mobility, migration, water and food access, security, peace and justice and so forth. Engineers will play a key role to tackle these challenges and deliver on the the United Nations Sustainable Development Goals (UN SDG). They will have to develop innovative and impactful approaches, breaking old rules and recipes.

CHANGING ROLES, SKILLSETS AND MINDSETS

Engineering roles are breaking away from what they have been. Engineers move beyond the 20th century style ‘how-to-do it’ engineering and need the skills to work in ‘what-to-do and why-do-it?’ engineering functions.

> “Training data literacy and human literacy as well as mindsets has to become an integral part of the engineering fundamentals, just like the technological literacy of mathematics, physics and engineering sciences.”

Engineers collaborate and work together in flatter hierarchies in uncertain, sometimes chaotic environments. Increasingly they have to ‘think statistically’ rather than ‘deterministically’ and will be supported by intelligent assistants with algorithms and generative design software. These robots become a real design partner for the engineer, not only representing or optimising things, but making decisions for the designer.

Good employability requires graduates of S&T universities to have a mindset of continuous upskilling and relearning. They need the coherent ensemble of deep working knowledge of engineering and technology, a broad range of durable skills, competencies that are related to innovation, marketing and services, and a strong sense of their actions and impacts. The habitat of almost all engineering graduates is in innovation, where understanding the customer and truly caring about their needs and experience is essential. Innovation will be the emerging key competency for all engineering graduates.

SKILLSETS OF TECHNOLOGICAL LITERACY, DATA LITERACY AND HUMAN LITERACY

Apart from the engineering fundamentals, the exponentially growing domain-specific body of knowledge and fluency in analytical reasoning and problem solving, technological literacy will get new accents. There can be no doubt that any engineer, any professional, shall be data literate. The integration of physical and cyber systems shall get the highest priority in engineering education, research and innovation.

Many universities are struggling with the question of what data literacy skills have to be taught at what levels. Graduates will need a good working knowledge of and excellent skills in mathematics, algorithmic thinking and programming, statistics, predictive analytics, domain knowledge about smart manufacturing, sensors, Internet of Things, Artificial Intelligence (AI), machine learning, data visualisation techniques, cloud platform, cybersecurity, etc. It ensures that they can operate successfully in an increasingly ‘data–rich’ engineering environment. The inclusion of these Industry 4.0 and innovation related skills must be a driving force for change in all engineering educational programmes.

Another literacy that is gaining prominence is human literacy. The more technological we get, the more we need people who have a broader framework. Human literacy is about empathy, communication and the ability to connect people, as well as autonomy, agency, self-efficacy and emotional intelligence to function in the human milieu. They are set to play an ever more critical role in the Science, Technology, Engineering and Mathematics (STEM) field (‘STEMpathy’). In engineering business, where large corporations are trimming down in size and the so-called ‘gig economy’ is expanding, the mastery of these skills encourages the entrepreneurial mindset that society needs.

MINDSETS

Knowledge alone is not sufficient for a successful career in engineering. This is particularly true when engineering professionals are going to collaborate with intelligent machines that will do most of the lifting of information. Success in future careers in engineering depends on the combination of the skillsets of literacies, but to an even larger extent on a set of cognitive abilities. These are higher-order mental skills, mindsets and ways of thinking and beliefs about the world. All-round engineers with these cognitive abilities can only be produced by educational programmes that are enriched to develop breadth, both on a professional and personal level (Aoun, 2017).

Most important mindsets in the domain of engineering are critical thinking, holistic, systems thinking, entrepreneurial thinking, global mindset, cultural agility, and valuing learning over knowing. These are thinking modes that cannot be imitated by (networks of) intelligent machines and are unique for people. Other examples of mindsets that are important to nurture in engineering curricula are design thinking, data-driven approach, coalition building, taking the lead and playing by strengths, and 'getting things done'.

PREPARING STUDENTS FOR IMPACT-FOCUSED CAREERS

The skillsets of technical, data and human literacy and the mindsets the engineering world of work demands are rapidly evolving, faster than most universities can manage. With the emergence of AI in the engineering profession, robot-proof education will have to educate people to think in ways that cannot be imitated by networks of intelligent machines (Aoun, 2017).

DESIGNING LEARNING FOR HUMAN NEEDS

A major concern is that many educational programmes in the S&T domain do not align with the needs of the world of work or societal needs. It is a valid question to ask to what extent learners and employers will remain interested in the more traditional solutions from higher education. Learners become more demanding co-creators of educational services and more open to emerging educational providers. University diplomas may soon no longer be the only pre-requisite for the engineering professional world. The job market assesses the competency levels of their future employees themselves, based on a portfolio of accomplishments and personal synthesis of learning gains at university level and daily life. Increasingly learners want to take control of their learning path, prefer unbundled courses to linear curricula, in order to assemble them into individual curricula. In future students may spend less time in the classrooms at the university, and come back throughout their careers to update their skillsets with separate 'knowledge packages'. It will require new forms of teaching, certification and administration.

A major goal of higher education in the 21st century is to shift the learners' mind that learning is not just the acquisition of knowledge and skills, but a human quality and dispositions to cope with the uncertain world, a complex life and a changing work environment, and to tackle the big challenges such as the UN SDG. It requires pedagogies that focus on gaining skills to learn and relearn, and the agility to change perspectives. It implies that the current faculty-centred curricula (anchored by existing physical spaces, staff resources, time-bound schedules) have to be transformed into (more) learner-centred and meaningful curricula.

"We need to develop realistic teamwork, not heroic individuals."

Bachelor programmes usually prepare for complex engineering activities related to conceiving, design and implementation of products, processes and systems. Impact-focused learning can be achieved by a connective spine of design projects about authentic subjects, possibly citizen-science projects. They require compelling design and respective research questions whose potential outcomes have relevance and meaningful impact. Master curricula have to prepare the students for innovative engineering activities that often cross disciplinary boundaries. Innovation should run like a thread through the fabric of all Master curricula. The trend toward ever deeper specialisation and solitary work in Master degree programmes shall be overturned.

Impact-focused education accentuates experiential learning and is meaningful for students. It requires the accentuation of the relationship between engineering and society, where societal relevance should be the centre of engineering. Increasingly curricula have to involve thematic studies across disciplines, human-centred and project-based learning with real-world connections, and integrate work-based learning. Learning in randomness outside the academic cloister is the most effective teacher, but only when it is combined with student self-reflection and self-awareness.

The recent Massachusetts Institute of Technology study (Graham, 2018) about the global state of the art in engineering education confirms that the five curricular themes that become increasingly prominent, are well in line with impact-focused education:

- Student choice and flexibility (educating students in the profile that is more oriented to their ambition, aspiration, future career);
- Multi- and interdisciplinary learning (in collaborative design or applied-research projects);
- The role, responsibilities and ethics of engineers in society (solving human challenges and problems facing society);
- Global outlook and experience (working across nationalities, cultures and disciplines);
- Breadth of student experience (more choice, learning beyond the engineering disciplines).

PROFESSIONAL ENGINEERING CULTURE

Students are inspired to collaborate in interdisciplinary team projects, preferably in collaboration with Social Sciences and Humanities (SSH), and apply and transfer their scientific and engineering knowledge to the infinite contexts of real life. Connective spines of innovation, design or applied-research projects in curricula bring together students and staff from diverse disciplines, non-academic stakeholders of engineering business and Non-Governmental Organisations (NGO). They stimulate community building and move towards more outward-facing curricula with impact.

Today's reality is that many curricula in S&T universities have quite rigid structures and leave little freedom of choice for the student. Master programmes are supposed to foster the development of students to become young scientists as well as professional engineers who contribute to economic development and growth. Many Master programmes currently fail in training the students in understanding the larger contexts, which is a crucial to build upon, to find - or better, to create - a new job when their job disappears.

"You cannot understand or solve complex problems without the knowledge and tools of multiple disciplines."

Another important driving force for change is found in the need for multi- and interdisciplinary learning opportunities with student-led choices. These must be full of opportunities for students to personalise their graduation profile and pursue their own ambition and interests. In these projects it is the student who defines his or her personal learning goals and outcomes in relation to these projects, and determines how these will be achieved and reported in portfolios that stretch out over the full study programme. Portfolios with a synthesis of skillsets and mindsets that have been accomplished may soon be equally important as university degrees as a prerequisite for a job.

There is a clear trend of an increasing demand for differentiation, not only from the students but also from the job market. The integration in curricula of different roles in the engineering profession (Kamp, 2017) that are orientated towards future professional needs, may function as magnets to which students feel attracted and motivated, and guides the individual student. Engaging students with specific roles an engineer can play in real-world open-ended complex problems, makes them more adventurous, develops their self-awareness, motivates them to take ownership of their study, and helps them to develop into leaders in society, not just engineers.

ONLINE EDUCATION

Many face-to-face universities in S&T consider continuous education as an interesting complementary offering, next to their regular degree education. Online and open education are seen as modalities that provide flexibility to the educational system to off-campus students. But it also carries the risk that universities develop into conveyors of online courses.

Blended education is the dominant trend of innovation in on-campus curricula, as universities will not abandon face-to-face education (yet) for their Bachelors or Masters students. Online education is one of the tools to better align with student needs: less facility and time constraints, better situated contextual learning, more exposure to the real world of companies and technologies, improved learning experience like self-directed learning in a 24/7 type of communication and access (Vries, Klaassen, Ceulemans, & Ioannides, 2018). It is also seen as a promising field for universities for increased offering for new kind of learners related to lifelong learning (Henderikx & Jansen, 2018).

The developments in online and open educational resources have a major impact on the evolution of STEM education. Fundamental engineering knowledge is increasingly commoditised, and its learning is shifting to blended learning. In 10 to 15 years' time it may be way too expensive and time consuming for young students to learn basic engineering fundamentals and other content that can also be picked up online through personal learning with the support of learning analytics. Particularly Bachelor curricula are expected to evolve into a blend of off-campus personalised online learning and hands-on experiential learning in lab spaces on campus, in companies or makerspaces.

We move toward a technology-enabled era of learner-centred learning in which the students get what they specifically need and in which they, supported by intelligent assistants (avatars), largely teach themselves the fundamentals of engineering, skillsets and mindsets.

CONTINUOUS LEARNERS

Continuous learners are an emerging segment. Portfolio careers and the need for workforce agility in the gig economy are increasing the demand for continuous development. Continuous learners are 'consumerised' and want full control of their learning path. They want, just like the regular student, learning that is learner-centred, affordable, technology-enabled, accessible, and preferably creative and innovative. Increasingly they follow separate packages of knowledge, delivered by the best lecturers and available from a pool of modules, to rebundle them into a personalised curricula.

S&T universities that have the aim to make continuous education part of their mainstream activities, will have to co-design curricula and courses in close partnership with employers and students. This will lead to a more intense involvement of engineering business in education than nowadays.

LEARNING, UNLEARNING AND RELEARNING STAFF COMPETENCIES

TEACHING ENGINEERING MECHANICS OR TEACHING STUDENTS?

Traditional S&T universities focus on content and exams. For too long universities have been 'fixing the teacher' in teaching content better. Academic staff are subject matter experts. They often lack the method to teach engineering fundamentals and disciplinary knowledge, train social skills and foster mindsets in a coherent ensemble. It is these higher social skills and mindsets where the particular needs will be for a successful career in the field of science, technology and engineering in the emerging AI age of learning machines, avatars, automation and robotisation (Kamp, 2018).

The only thing that can make the difference in higher education will be the people. They are confronted with a plethora of tools and applications that are rapidly improving in terms of quality and applicability. Taking the innovations in pedagogy into consideration, strengthening the didactic professionalism of and trust in teaching staff have to be the norm. The role of the teacher is changing from the ‘sage on the stage’ to the ‘guide on the side’, or even to an enabler for learning. If staff are not willing or able to think, act and deliver ‘differently’, they may soon be redundant.

> “Many programmes seem not even aware that there is a problem in focusing almost completely on technical knowledge and processes in their engineering curriculum.”
>
> (Grasso & Burkins, 2010)

One of the biggest challenges for S&T universities is the agility and fostering of learning, unlearning and relearning of the academic staff, motivating them to co-design together with non-academic institutes or industries more student-centred, self-directed expansive curricula, and focus on research and design questions that have potential for societal impact. Students and lifelong learners are a different breed, they have different expectations, aspirations and needs, and are more ‘consumerised’ than universities are used to.

ACADEMIC CAREERS WITH EMPHASIS ON EDUCATION

The educational systems at many S&T universities may need wholesale change to accommodate teaching and learning for the future. For many decades the incentives for staff have been low as educational achievements are undervalued. Time has come to flip the existing culture of promotion on the basis of academic excellence (read research) and create a culture and structure in which teaching excellence and leadership in education will be weighed on par with research achievements, where career paths will be developed for academic staff who have an accent on education. The Royal Academy of Engineering (UK) launched a teaching framework that enables S&T universities all over the world to implement career emphasis on education.

Another challenge is that traditional S&T universities are structured in monodisciplinary faculties and departments. They have to transform and deliver interdisciplinary education without being highly interdisciplinary themselves. This will require a major mind shift and upskilling of staff as well as higher management and programme bodies.

ACADEMIC STAFF AS ROLE MODEL FOR STUDENTS

S&T universities are full of scientific staff who do not always have experience in engineering practice, which in extreme cases may lead to a disconnection between the academic world and the world of engineering practice. This can be a challenge at research-oriented universities, where the tendency is to narrowing the templates for recruiting academic staff and thus reducing the chance for people with a non-academic background to bring their experience, tacit knowledge, role models, empathy and creativity in engineering practice to the classroom.

It is therefore increasingly important to involve alumni in engineering education and attract more engineers with a personal experience in the private sector and select those worthy of being role models (SEFI, 2016).

They are in the position to give valuable counseling, supervision, consultation or intervision in particularly project work that can be messy, social and playful, where academic staff increasingly lack practical skills in engineering design processes, systems engineering, project approaches, or in the social or professional skills of team coaching, conflict management, negotiation, professional behaviour etc.

MAKING AS LEARNING

Creating is the most complex cognitive process in Bloom's Revised Taxonomy. The best way to learn is by creating, making, developing, exploring something, trying, failing, and analysing the failures, while making use of all tools and facilities the engineer will have available at his fingertips. At the heart of every engineer is a maker-instinct!

Makerspaces have to engender creativity (which is not a trivial issue at all), give the students a great deal of freedom, and provide conditions for invention. Students embark on challenges that are always related to meaningful real-world problems or research questions that are expected to have potential and palpable impact on society. Students go from ideas to physical concepts in multidisciplinary teams of students, staff and external partners to pursue creative and innovative answers to the world's challenges and open-ended questions.

Makerspaces can be a powerful expression of an institution's footprint. They create ownership of learning processes, even if it is not perfect. Makerspaces will become more important when educational programmes evolve into a blend of off-campus personalised online learning and hands-on experiential learning. Framing impactful experiential learning in the regular curricula is still a challenge. Also this will require a mind shift in management, teaching staff, administrators, organisational bodies, and students as well.

In the test-obsessed culture at universities the discussions about assessment of such experiential learning in makerspaces are always cumbersome. Marks of summative assessments are usually no inspiration to further understanding and learning. Makerspaces add more value and impact to learning outcomes when tests and marks are replaced by portfolios that are reviewed and assessed by the peers of the students. In these cases students should be coached in defining personal learning goals, writing a portfolio of accomplishments, and providing feedback to their peers. Also in engineering practice engineers learn from their senior colleagues. Why not incorporate this dimension in our teaching through peer feedback for and by students?

Makerspaces are always linked with specific entrepreneurial environments in which teams of students can develop and prototype their ideas. Based on specific coaching, start-ups can emerge and be confronted with the real life of a company with challenges such as convincing investors, structuring a good business plan and adapting to an already existing market.

STRENGTHENING UNIVERSITY-INDUSTRY COLLABORATION

Besides being an academic discipline, engineering is a practice-based profession. In their study programme students therefore have to get a taste of genuine research, engineering and design by learning-by-doing, and meet their role models in universities and industry. The professional workplace is the environment in which the impact of technological change is felt most strongly. Universities shall therefore address the strategies employers are seeking to accomplish and the ways technological change and innovation shape the industries. Study programmes shall not only be aligned with the latest developments in research and science, but also in engineering practice (Kamp, 2018).

Also in lifelong learning models, universities have to aggressively engage with industry to co-design curricula and course content, collaborate on applied research, and offer work-integrated learning. Especially in this age of acceleration and digitalisation this requires a strong and enduring partnership between industry and academia.

EMPOWERING LEADERSHIP

The role of education institutions shifts from being a repository of knowledge to teaching learners to curate, challenge and extend knowledge, and redefining research and teaching methodologies via technology (Cawood, et al., 2018). In addition, new incomers in education, from all over the world, appear with breakthrough models in education, such as the NMITE initiative or the 42 school. Then, our universities will need all their capacity to transform themselves deeply to serve a changing society and a profoundly changed world and to stay relevant and meaningful for the next generations.

Change in education is often at risk because it is hardly the focus of any ‘ranking management’. Establishing a new paradigm for engineering education at the S&T universities demands a clear educational vision and strategy, where management has to demonstrate personal commitment (Henderikx & Jansen, 2018). It is often the young academic staff who are not yet tied to the old ways of doing things, who can make change happen, in close collaboration with more senior students.

> “The university of the future will derive its right to exist primarily from being active in the world and by producing knowledge for the world.”
>
> (Van der Zwaan, 2017)

Educational change has to be drawn on feedback, evidence and ideas from across the university hierarchy, and beyond the university. Management has to nurture an educational culture of continuous experimentation and innovation and be prepared to accept failure. Deregulating the environment (flexibility in rules and regulations), and last but not least, incentivising staff to experiment and innovate education are important enablers of changing educational culture. It’s not the institution that causes change, but it is the people.

INSTEAD OF A CONCLUSION

Educational change will not be driven by S&T but by university strategy, the changing nature of the student body and the decisions of individual faculty members. Too many academics are traditionalists whose education is a mechanistic solo-activity and whose institutions revere their traditions and habits. They keep the focus on content and exams and decide not to think about innovation in the curricula or courses, simply because it represents a departure from how things are done. They neglect the mismatch between job market needs and keep the focus on the easy to handle technical knowledge in the current curricula.

We have entered an era that will rock the foundations of engineering education which is in the throes of a major shift. Making fundamental changes is the only way to reap the benefits of pedagogical and technological innovations in education and better prepare graduates for the increasing and very different demands of the new world of work.

Our association is in the position to envision these changes and make choices on how to adapt S&T education in Europe. It can thus provide the universities with a compass for strategic planning and updating educational vision. The actionable forward-looking recommendations below are a set of key topics that will enhance employability and career development of the graduates of our Members. They indicate what changes are important and necessary to remain relevant to our societies and economies. The diverse perspectives in education of the university members as well as the agility of the programmes to transform, will be crucial for us not to only to react to change, but take the lead in the future of S&T education in Europe.

1) Skillsets and mindsets for 21st century engineers

– Nurture mindsets and meanings in curricula;
– Make innovation the major thread in the fabric of Master programmes;
– Design learning for humans by a broadening of disciplinary curricula in Bachelors and Masters with arts and SSH;
– Integrate scientific and professional integrity and business ethics in engineering curricula;
– Make the culture of data literacy tangible in all educational programmes;
– Empower students in labs and makerspaces (intra- and extracurricular) to foster leadership, ethical behaviour, deep collaboration, interdisciplinarity and creativity.

2) Pedagogical and technological innovations in education

– Develop agile curricula with flexibility and freedom of choice for the students;
– Foster peer-to-peer learning;
– Nurture a culture of experimentation and innovation in education on a limited scale, within a strategy for implementing more widely successful innovations;
– Empower staff to improve and innovate education in short-term agile iterations in a data-driven manner, and disseminate the outcomes.

3) Continuous/life time education: continuous upskilling and relearning

– Incentivise and develop continuous professionalisation of staff in concert with academic career opportunities in education.

4) Educational strategy and leadership

– Empower leadership and develop an institutional vision and strategy for education;
– Intensify the collaboration with industrial partners and create more opportunities for engineering practitioners in the classroom, engineering projects and internships at companies;
– Promote impact-focused education through interdisciplinary student-centred projects with societal relevance (where societal relevance is the centre of engineering).

ANNEXE I: ABBREVIATIONS

ABBREVIATION	MEANING
AI	Artificial Inteligence
DANCE	Data, Algorithms, high-speed Networks, Cloud and Exponential Moore's Law
GAFA	Google, Apple, Facebook and Amazon
NGO	Non-Governmental Organisation
SSH	Social Sciences and Humanities
STEM	Science, Technology, Engineering and Mathematics
S&T	Science and Technology
UN SDG	United Nations Sustainable Development Goals
VUCA	Volatility, Uncertainty, Complexity and Ambiguity

ANNEXE II: BIBLIOGRAPHY

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