MAXIMISING ACADEMIC AND SOCIAL OUTCOMES

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ABSTRACT

The MASOEE project brings together engineering faculties in the EUniWell alliance to share best practices for teaching transversal skills so that engineers contribute to societal well-being. The study combines the expertise of several engineering faculties at European universities. It focuses on sharing and developing expertise to improve the social outcomes of engineering students. Namely, researchers examine the similarities and differences between partners regarding their student bodies, teaching, programme structures, and institutions' culture. Moreover, the work also explores how transversal skills are taught, what student attitudes are in terms of learning these skills, and how educators can better teach them.

The research design includes several activities across four work packages (WPs). To ensure that partners use the same skill descriptions, we use well-established organizations' existing definitions. WP1 strives to identify best practices within EUniWell based on the 15 entrepreneurial competencies defined in EU EntreComp Framework. WP2 targets engineering students' ability to solve complex challenges, communication, and networking skills defined in the "21st century skills" by the World Economic Forum. WP3 investigates the engineering schools' capacity to train engineering students in sustainable competence, forming responsible engineers capable of developing sustainable solutions using the skills defined by the EU GreenComp. WP4 supports the other packages with engineering education research, specifically data collection and analysis, knowledge forming, and evaluation. The project runs from August 2022 until September 2023.

The MASOEE project partners gather knowledge within their organisations through joint surveys and focus groups and collectively identify and share best practices. The engineering identity, taught as transversal skills by participating partners, can evolve from a traditional technologist identity along three paths: the self-made engineer, the progressive technologist,

and the responsible engineer. By sharing best practices for teaching these skills, we believe we will better understand what the future engineer - who integrates all three identities – will be.

KEYWORDS

Social competencies, self-made engineer, 21 century skills, Responsible engineer, Entrepreneurship, Sustainability competence. CDIO standards: 3, 5, 7, 8, 9, 10, 11

INTRODUCTION

The EUniWell alliance mission is to resolve the paradox of Europeans' relative levels of prosperity against the global challenges in society they face: health, environment, political instability, and defence. Maximising Academic and Social Outcomes in Engineering Education (MASOEE) interprets this contradiction for the engineering profession as how to best teach the non-technical skills to ensure engineers make their utmost contributions to societal wellbeing. Our strategy is to bring together the expertise of Birmingham, Florence, Linnaeus, and Nantes engineering faculties. These EUniWell engineering schools will share and develop expertise to improve the social outcomes of engineering students (Figure 1).

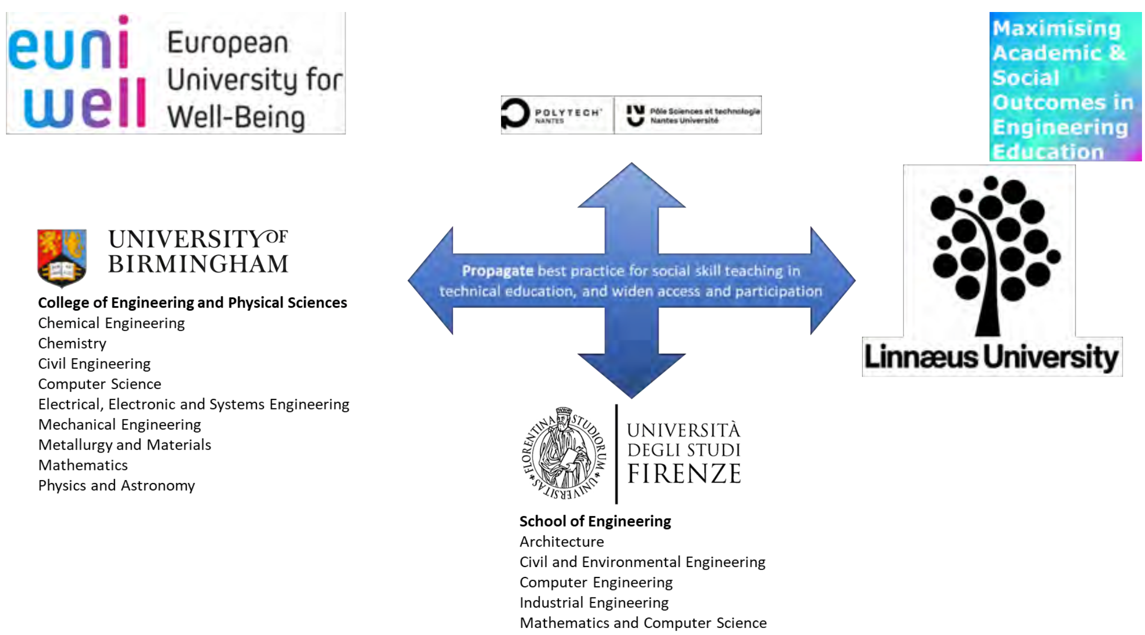

Figure 1. MASOEE partners

Figure 2 shows an overview of the project. Several activities are planned with outputs. Three skills sets are defined, and each partner assumes responsibility one of them to run workshops and data collection activities (right box). The school of education at Birmingham will advise the format for data collection (left box) so that research questions can be answered. The activities will result in a set of case studies which consider the adoption of best practice across institutions (centre boxes). The following sections describe each activity and provide some context.

MAXIMISING ACADEMIC AND SOCIAL OUTCOMES

This is the core of the project. An academic outcome for engineering is defined as the technical skills that are acquired by students in their studies. These include the basics of science and mathematics, design, and analysis skills, as well as the use of engineering tools and methods. In contrast, non-technical skills are referred to as “social competences” where outcomes are defined by:

1. How partners teach non-technical/social competencies in the context of a technical education.

2. How partners widen participation of disadvantaged groups and narrow attainment gaps.

How do partners teach non-technical/social competencies in the context of a technical education?

Engineers solve problems by applying scientific knowledge and principles. Consequently, engineering culture is considered distinct from other disciplines (Van den Bogaard, 2021) and purposely depoliticized (Cech E., 2013) so that it is best for engineers to practice independently of public affairs and/or leave such issues to other professionals such as social scientists and politicians.

Figure 2. MASOEE activities

This narrow focus on technical competence leads to students acquiring an engineering identity that can be considered a “traditional technologist” (Berge, 2019). Contemporary engineering education in most faculties has shifted away from this identity towards 3 new identities; each of which corresponds to a skill set defined in the MASOEE project (Table 1). These emerging identities for the engineer are: the “self-made engineer”, the “contemporary technologist”, and the “responsible engineer”.

The “self-made engineer” can be considered one who develops a meritocratic and individualistic ideology through their study primarily to improve their employability in the job market. This is partially promoted through learning enterprise, innovation, and creativity skills. This orientation is sometimes at the expense of beliefs in public welfare including professional and ethical responsibilities, and the consequences of technologies (Cech E. A., 2014).

Table 1. Engineering identities [Berge,2019] mapped to MASOEE skills

Engineering identity as defined by (Berge, 2019)	**MASOEE skills**
Traditional technologist (status-quo)	Science and maths, design, analysis, engineering tools and methods.
Self-made engineer (neoliberal trends)	WP1 Entrepreneurship: Innovation, enterprise & creativity.
Contemporary technologist (progressive trends)	WP2 Solving complex challenges: Communication & networking.
Responsible engineer (sustainability trends)	WP3: Sustainability competence: Technical, social & environment responsibility.

The “contemporary technologist” is someone who retains the importance of technology skills, yet acknowledges the need to acquire the generic, softer professional skills such as report writing, project management and team skills which are easy to operationalise. Like the “self-made engineer”, the motivation of the student to adopt this identity is typically improved employability, which serves the modern neoliberal agenda of universities where competition and value of money are key foci (Berg, 2016). A key resistance to teaching these professional skills is the ability of engineering academics to teach them due to lack of capacity; capability, motivation, and opportunity.

The “responsible engineer” encourages a morally responsible stance to be taken where technical skills serve the greater good of society and the environment. The chief focus is on ethical behaviour with a greater consideration of how technology is developed and for what purpose. Typically, the responsible engineer follows the sustainability agenda for social wellbeing, climate change, energy, and food security.

To summarise, modern engineering curriculum has moved from educating the student to the professional identity as the “traditional technologist” towards the “self-made engineer”, “contemporary technologist”, and “responsible engineer”. Each of these new identities is valuable and not mutually exclusive. Therefore, understanding how each of these three identities and their underlying skills sets are taught by MASOEE partners might reveal key insights into how the engineering identity is formed.

The hidden curriculum

Fundamentally engineering is about applying scientific methods and knowledge to create new products, processes, and services (Lucas, 2014). This encourages engineers to maintain a mindful separation of “technical” and “social” competence – an ideology referred to as “social-technical” dualism (Faulkner, 2007). This dualism can be reinforced by how curricula is designed and delivered. Appreciably, separate learning units for skills, delivered by non-engineering experts creates an idea of the hidden curriculum; non-technical competencies are duly taught and learned, but not widely thought of as an engineer’s problem, not fully integrated into day-to-day engineering habits, or practiced post-study. This phenomenon is known as “the hidden curriculum” (Tormey, 2015).

How partners widen participation of disadvantaged groups and narrow attainment gaps

The global marketplace for higher education and its neoliberal trends, where students are customers and higher education produces employment-ready graduates, leads to social outcomes in education being considered chiefly through graduate destinations and earning potential (Berg, 2016). Since engineering is a relatively well-paid profession, the ultimate social outcomes of studying engineering and then entering its profession for the individual can be considered net positive. Thus, engineering education can be a force for social mobility by widening access for disadvantaged students, as long as the learning environment delivers an equitable education and closes any attainment gaps between disadvantaged groups and the mainstream cohorts.

MASOEE partners have different definitions for what is considered a disadvantaged student, so what these differences are and how they are dealt with will be a valuable knowledge exchange.

WORK PACKAGES (WP1-3)

Professional skills inventories are well understood and described in the literature. The MASOEE project will involve knowledge exchange of how these skills are embedded in programmes and identify best practice. So that all partners share a common definition for discussing the skills sets, the project will draw on existing skill inventories and taxonomies: for WP1 EU EntreComp (Bacigalupo, 2016), For WP2 WEF 21st Century Skills (World Economic Forum., 2016), and for WP3 EU GreenComp. MASOEE partners will identify the parts of their curricula where similar learning outcomes reside in the curriculum mapping exercise. A final work package, WP4, considers research design and analysis.

WP1 Entrepreneurship (Innovation, enterprise, and creativity)

To create “self-made engineers”, the skills needed including are described in the EU EntreComp Framework (Bacigalupo, 2016) – see Figure 3.

Figure 3 Visualisation of EU Entrecomp (Bacigalupo, 2016)

There are 15 competences are equally split equally across 3 areas – “Ideas & Opportunities”; “Resources” and “Into Action”. The framework adds further value by providing a progression model for skills and provides 442 related learning outcomes for consideration/inspiration in defining modules and programmes.

WP2 Solving complex challenges (Communications and networking)

To create “broad technologists”, Communications and networking involve a set of skills around professional capabilities such as project management, teamwork, and written communication. These are best captured by the “21st century skills” by the World Economic Foundation (World Economic Forum., 2016) (Figure 4). This splits the skills into 3 categories: foundational literacies, competencies, and character qualities.

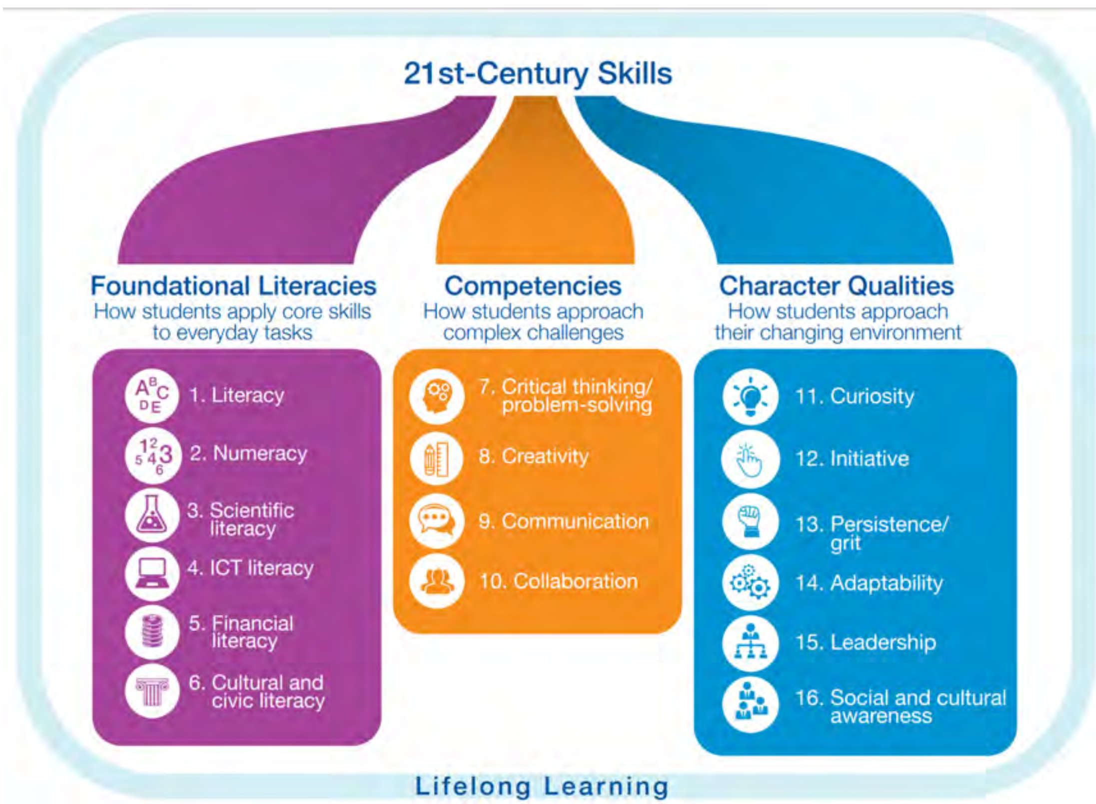

Figure 4 Visualisation of 21st Century Skills (World Economic Forum., 2016)

WP3 Sustainability competence: Social, environment, and technical responsibility

To create “Responsible engineers”, the EU GreenComp framework serves as a useful model to capture the skills (Bianchi, 2022) – see Figure 5. This considers sustainability across 4 areas: embodying sustainability values, embracing complexity in sustainability, envisioning sustainable futures, and acting for sustainability. In each area there are several skills.

Figure 5 Visualisation of EU GreenComp from [Bianchi (2022)]

Sustainability is considered a transformative technology, that together with digitalization creates a framework for future products and markets (Guandalini, 2022). This development increases the need of knowledge for the engineer to be able to handle and master the skills and key competences needed (Redman & Wiek, 2021). The engineer will need a broader toolbox of and be able to connect different fields and competences (Venn et al, 2022). The student should during the education get the opportunity to train the key competences for sustainable development by learning to solve complex challenges (Unesco, 2020).

Systemic adoption across partners

MASOEE partners will share best practice through sharing case studies. Moreover, to facilitate integration of new practice into their institutions, the case studies will be structured drawing on the literature of diffusion or innovations framework – notably the propagation paradigm (Froyd, 2017) where the key object is to maximise the efficacy and the fit to the partner to allow for meaningful adoption (Figure 6). The characteristics of a propagation paradigm include:

- The focus being fit rather than evidence of efficacy. This requires dialogue with partners for how to adapt an innovation at a partner.
- The innovations should be characterised by usability to provide generalisation to other settings, rather than strong data.
- Partner interactions through case study presentations ought to support adoption rather than raise awareness.
- The different instructional systems, e.g., Canvas, Moodle, must be considered as part of the case study so that technical frictions can be reduced.

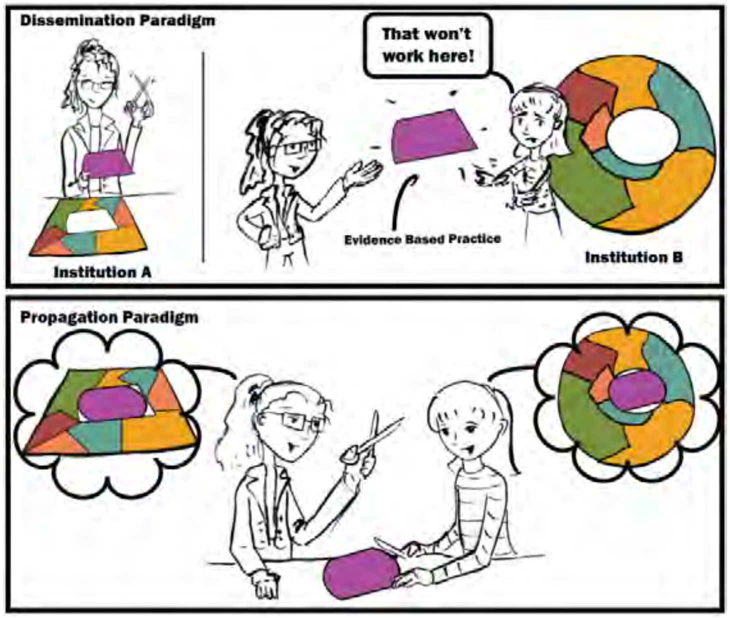

Figure 7 Visualisation of the propagation paradigm and differences with deamination paradigm (Froyd, 2017)

Engineering education research (WP4)

The Engineering research activity will guide the data collection in the study so that it can help answer some key research questions for the project. The three research questions are:

- RQ1: What are the similarities and differences between engineering partners, their student bodies, teaching, programme structures, and institution culture?
- RQ2: How are the skills currently taught and embedded in programmes? What are student attitudes to learning these? How do we define and measure social outcomes?
- RQ3: Which new approaches can we employ to better teach these skills that deliver better social and academic outcomes?
- To answer these questions, the following data is captured:
    - Curriculum mappings – where skills are taught in the partners.
    - Student questionnaire on attitudes to learning non-technical skills.
    - Staff questionnaire on attitudes to teaching non-technical skills.
    - Semi-structured interview and focus group protocol on student attitudes to partner teachings.
    - Semi-structured interview protocol on staff attitudes to other partner teachings.

Once the data is captured, responses will be transcribed, translated, and coded before analysis techniques employed following a mixed-methods approach.

- For analysis of attitudes: Exploratory factor analysis (Fabrigar, 2011), Self-determination theory (Deci, 2012):

- To compare differences between partners: Activity theory (Nussbaumer, 2012), Legitimation code theory (Maton, 2015).

Mixed methods

The MASOEE project aims are to examine the similarities and differences between institutions in terms of student bodies, teaching, programme structures, and institutional culture. However, we also want to explore how skills were taught, what student attitudes were in terms of learning these skills, and how we can better teach them. Whilst it is possible to gather some of this data within a quantitative manner, exploring student attitudes needs a more qualitative approach, leading to the decision to adopt a mixed method research design.

Johnson and Onwuegbuzie (2004) argue that when comparing a single method research approach with a mixed method one, it is the diverse nature of mixed methods that results in “superior research” (Johnson and Onwuegbuzie, 2004, p14). They further argue that mixed methods allow researchers to develop a greater understanding of the strengths and weaknesses of both singular paradigms, which then allows the research team to develop strategies by using and combining methods that would complement each other and ultimately be of most benefit to their study (Johnson and Turner, 2003; Johnson and Onwuegbuzie, 2004).

It is important to establish how each component within a mixed method project interacts (Denscombe, 2017), for example, does a component create a more complete picture or does one component guide another component. To help understand how this mixed method research has been structured, the research questions were broken down into each method used to help answer it. The different methods used will be: documentation analysis, surveys, followed by interviews an focus groups to reflect different aspects (Figure 7).

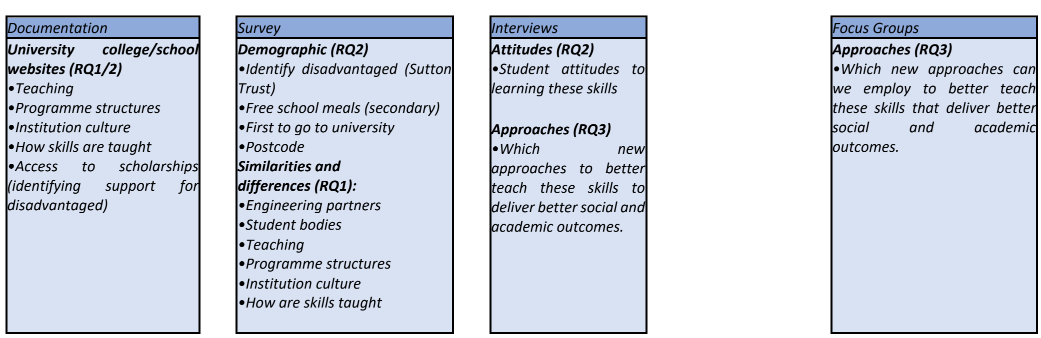

Figure 7 Overview of research questions and methods used to answer them

Reflecting on how each component relates to the others (Denscombe, 2017), the documentation and survey aspects are both designed to obtain an overview of current practices, demographics, and similarities and differences. The interviews and focus groups are designed to explore attitudes and approaches and will build on information found within the documentation and survey phase. There is a mixture of qualitative and quantitative approaches required.

CONCLUSION AND DISCUSSION

EUR-ACE accreditation standards, CDIO, and a globalised engineering educator profession cultivate the standardisation of degree programmes across the European continent. Despite this, engineering faculties have different cultures and contexts in which they have developed their programmes to teach engineering skills to best serve their employment markets and optimised to suit their unique student populations. All partners have practises for students to learn these soft skills, however different approaches, and methods to train them. The first part of the project has compared program structures and teaching cultures, finding both similarities and differences. By meeting in developing workshops, a creative learning process has been started and the questions are brought into focus, but what is the common core of the different education systems? The MASOEE project aims to maximising both the academic and social outcomes in engineering education through systematic sharing of knowledge and expertise across borders to discover differences in approaches to teaching skills and how they might be adapted in new contexts.

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BIOGRAPHICAL INFORMATION

Neil Cooke has vast experience from research and teaching activities covering systems and data engineering, multimodal physiological signal processing, artificial intelligence, affective computing, visualisation and virtual reality, medical informatics; educational technologies and engineering education. His work spans several industrial domains including defence training and simulation; medical, telecommunications infrastructure and education. He has designed, developed and delivered 100+ credits of different innovative teaching materials at all degree levels, supervised upwards of 70 project students, contributed to higher education teacher training, conducts Engineering education research, lead designing and implementing laboratory curriculum change initiatives across STEM faculties, and has extensive international student recruitment and outreach experience. He has co-authored 27 publications in peer review conferences and journals. He served on the board of directors for the European Society of Engineering Education (SEFI) between 2017 and 2022, and currently chairs their special interest group on engineering skills, as well as co-writing, producing and presenting their “European Engineering Educators” podcast.

Jörgen Forss focus areas are environment and resource utilization in both teaching on engineering programs, interdisciplinary environment, and sustainable development courses. He strives to put the student and science at the centre through different pedagogies e.g. flipped classroom. He also supervises degree workers in water, materials, and resource matters. His research is connected to water, processes, and purification, preferably with connections to energy and environmental applications. Some previous projects have had connections to developing countries and how concepts around purification can be built with small resources. Projects his been involved in: purification of textile dyes, identification of fungi and bacterial composition in water purification filters, foam formation in septic tanks, filter purification techniques, algae as carbon dioxide filters for biogas, water use in apartment buildings.

Sarah Chung qualified as a primary school teacher, specialising in English, in 2004. She has worked throughout Key Stages 1 & 2 as both a class-based teacher and supply. After becoming a governing at her children's school in 2015 she developed an interest in educational leadership and decided to pursue an MA in School Improvement and Educational Leadership at the University of Birmingham. The MA supported her development as a governor and her later roles as Chair and Vice-Chair of governing bodies in the West Midlands.
In 2018 she was awarded a CoSS Scholarship and began her PhD journey within the School of Education, exploring the role of governor training. During her second year (2019/20) she became a Westmere Scholar, supporting PGRs across the University of Birmingham. In her third year, she has taken on the role of General Co-Editor of Ad Alta: The Birmingham Journal of Literature. Now in her fifth year she's based in the School of Education.

Jesper Andersson is a Professor in Computer Science at Linnaeus University. He received his PhD. in Computer Science from the Department of Computer and Information Science at Linköping University in 2007. His research focuses mainly on Software Engineering techniques and methodologies supporting the development of smarter systems. He has published several papers in distinguished journals and conferences in Self-adaptive Software Systems, Software Reuse, and Software Ecosystems. He has also served in organization and program committees för several international conferences, symposiums, and workshops.

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